Habitats in Extreme Environments Senior Design Project

Wednesday and Thursday, July 27/28, 2011

Jerry Garcia

Agenda

Wednesday, July 27, 2011

Topic	Time
Introduction & Project Overview – Gloria Murphy	9:00 a.m. - 9:15 a.m.
Welcome – Education Program Office	9:15 a.m. – 9:30 a.m.
NASA Systems Engineering Overview-Jerry Garcia	9:30 a.m.- 11:30 a.m.
Lunch	11:30 a.m.– 12:30 p.m.
Senior Design Discussion- Craig Harvey	12:30 p.m.– 2:30 p.m.
Break	2:30 p.m.– 2:45 p.m.
Senior Design Implementation- Peter Schmidt	2:45 p.m.– 3:45 p.m.
Habitats in Extreme Environments Overview – Craig Harvey	3:45 p.m.– 5:00 p.m.
Optional Dinner (faculty's expense) - Fishlips Waterfront Bar & Grill, Port Canaveral	6:00 p.m.

Thursday, July 28, 2011

Topic	Time
KSC Tour- Susan Sawyer	9:00 a.m.- 12:00 p.m.
Lunch	12:00 p.m.- 1:00 p.m.
Habitats in Extreme Environments – Craig Harvey	1:00 p.m.– 3:00 p.m.
Break	3:00 p.m.– 3:15 p.m.
Habitats in Extreme Environments – Craig Harvey	3:15 p.m.– 5:00 p.m.

Senior Design Discussion

Wednesday, July 27, 2011

Senior Design Discussion

- **Break out groups (45 minutes)**
  - In groups of 3-4, complete the following and be ready to report on the following as a group.
    - Source of your senior design project topics.
    - Make-up of your senior design teams:
      - Single discipline, multi-discipline, etc.
    - Senior design administration
      - Who supervises (1 faculty, team of faculty, etc.), 1 or 2 semester
    - Things you have tried in your senior design projects that have worked well.
    - Things you have tried in your senior design projects that have not worked so well.
    - Problems you consistently have with senior design projects.
- **Break – 15 minutes**
- **Group Discussion (45 minutes)**
- **LSU Senior Design (15 minutes)**

LSU Senior Design

- **Gerry put in material**

Peter Schmidt

Habitats in Extreme Environments – Course Content Overview

Wednesday, July 27, 2011

Habitats in Extreme Environments Overview (1hr 15 min)

- Logistics & Structure
  - Overall timeline
  - Teaching, supervision assignments
  - Multi-disciplinary teams
  - Organizing contacts & topics with NASA [**get org chart with contacts]
  - Lecture/meeting schedules
  - Report/presentation schedule
- **Course Outline**
- **Syllabus**

Habitats in Extreme Environments

Thursday, July 27, 2011

Outline

- Course Material Overview (1 hour)
- Assessment (30 min)
- Lessons Learned (30 min)
- Faculty Participant Activity (1 hr 15 min)

Course Material

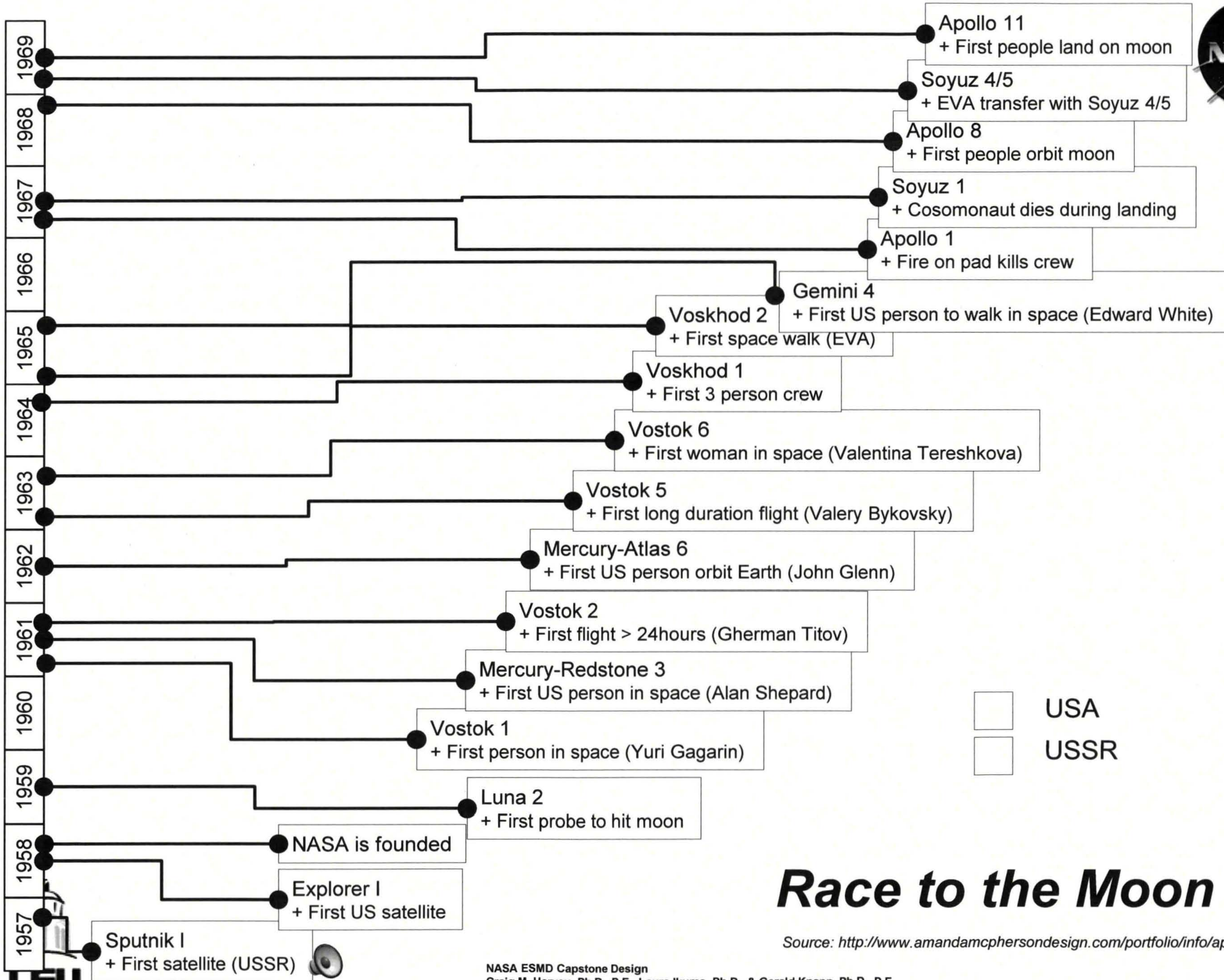
- **Four areas for lecture/discussion**
  - Space Operations
  - Systems Engineering
  - Habitat Requirements
  - Habitat Design
- **Sampling of material and discuss some of the things done to engage the students in material**

Space Operations Overview

01. Space Operations Overview
NASA ESMD Capstone Design

Outline

- Race to the Moon
- What are some Extreme Environments
- Return to the Moon
- International Space Missions
- Human Space Mission Design Issues
- Human Physiology: Human Factors and Psychology
  - Environment
  - Orbital
  - Safety and Reliability
- Tasks in Space



Race to the Moon

Source: http://www.amandamcphersondesign.com/portfolio/info/apollo11.jpg

CLASS ASSIGNMENT 1

Space History Assignment Brief

- **For this mission shall you decide to accept it (like you have a choice): Prepare a 7-10 minute presentation on the assigned program(s):**
- **Team 1:**
  - Mercury/Gemini
- **Team 2**
  - Apollo/Apollo-Soyuz
- **Team 3**
  - Shuttle
- **Team 4**
  - Skylab/Mir
- **Team 5**
  - International Space Station
- **For the program at minimum, explain the following:**
  - What were the objectives?
  - What were the challenges?
  - What engineering issues did they have?
  - What if any human exploration was involved?
  - What was the expertise of the crew (provided there was one)?
- **Due: 27 August 2010 in class**

Extreme Environments on Earth

- **Antarctica**
  - Living in Antarctica
    - Getting there
    - Surviving the cold
    - Food
    - Health and Wellness
    - Communication
  - Working in Antarctica
- **Submarines**
- **BIOSPHERE 2**
- **MARS 500**
  - Main Purposes
  - Experimental Stages
  - Location

Biosphere 2

MARS 500

- The European Space Agency (ESA) is undertaking a cooperative project with the Russian Institute for Biomedical Problems (IBMP) in Moscow, called Mars500. (http://www.esa.int/esaMI/Mars500/)

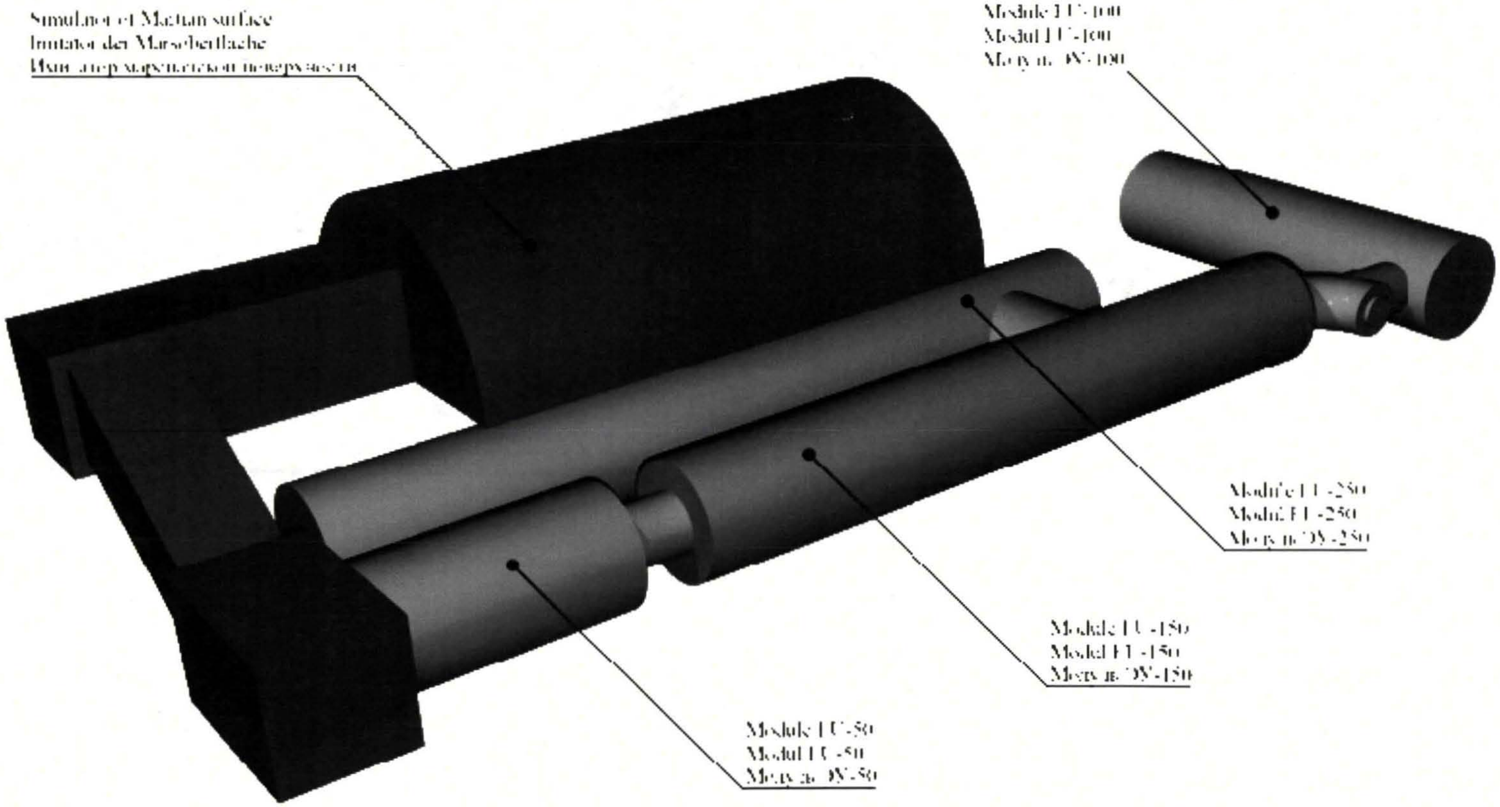
- A total of 640 experiment days, divided into three stages have been scheduled.

- During each stage, the crew of volunteers live and work in a mockup spacecraft.

- Communication with the outside world is limited and has a simulated 20 minutes delay.

- Supply of consumables is limited.

Modules of Experiment Facility



NASA ESMD Capstone Design
Craig M. Harvey, Ph.D., P.E., Laura Ikuma, Ph.D., & Gerald Knapp, Ph.D., P.E.

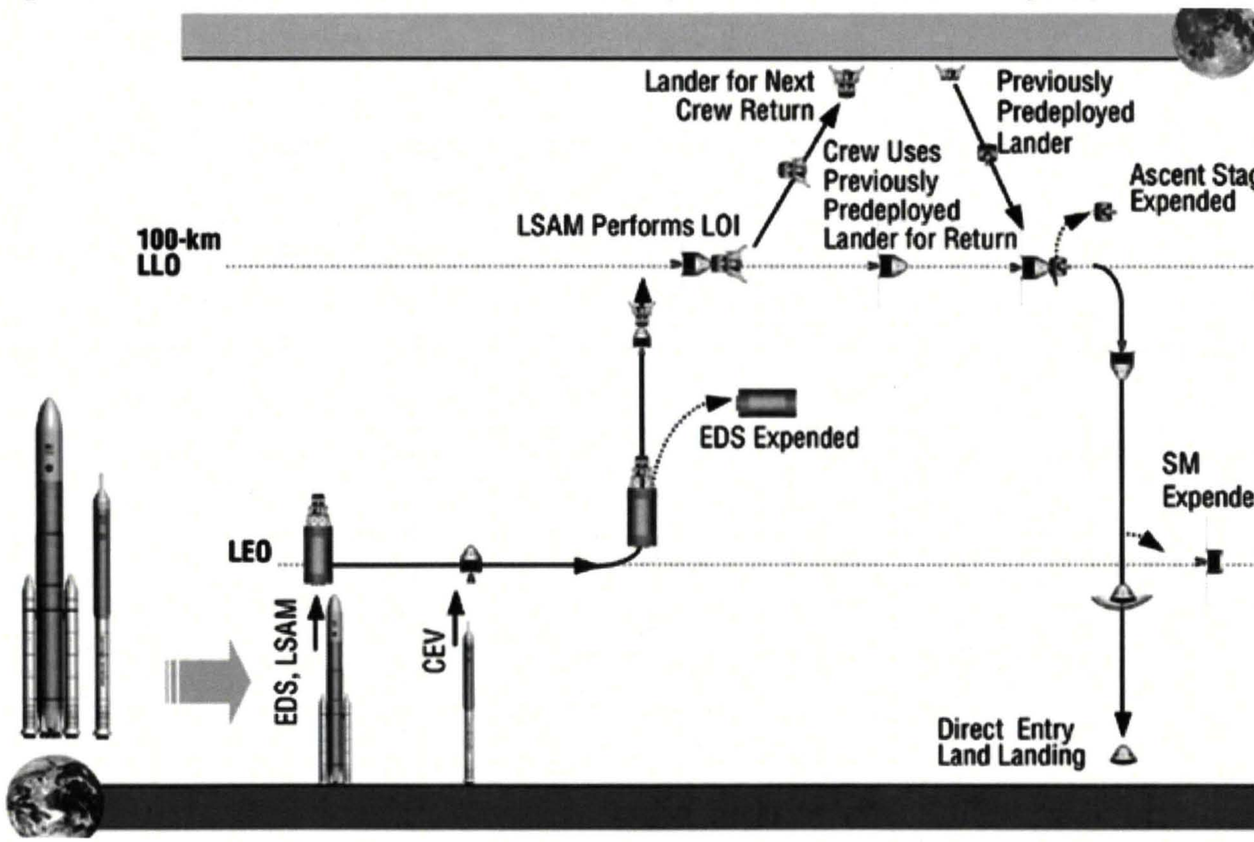
Design Reference Missions

- **Design Reference Missions (DRMs)**
  - A series of DRMs was established to facilitate the derivation of requirements and the allocation of functionality between the major architecture elements.
- **Three of the DRMs were for ISS-related missions:**
  - transportation of crew to and from the ISS,
  - transportation of pressurized cargo to and from the ISS, and
  - transportation of unpressurized cargo to the ISS.
- **Three of the DRMs were for lunar missions:**
  - transportation of crew and cargo to and from anywhere on the lunar surface in support of 7-day "sortie" missions,
  - transportation of crew and cargo to and from an outpost at the lunar south pole, and
  - one-way transportation of cargo to anywhere on the lunar surface.

DRM: Lunar Outpost Crew with Cargo

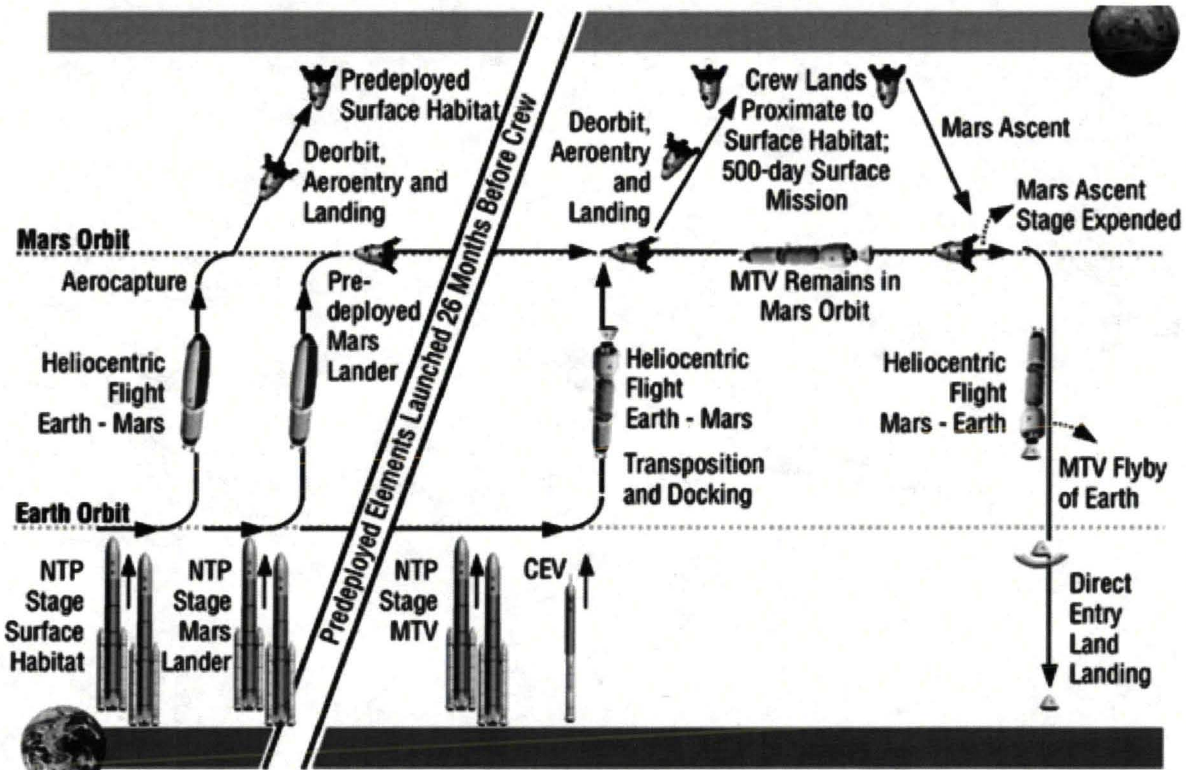
- **Primary Purpose: Transfer up to four crew members and supplies in a single mission to the outpost site for expeditions lasting up to 6 months. Every 6 months, a new crew will arrive at the outpost, and the crew already stationed there will return to Earth. The outpost is expected to be located at the lunar south pole.**

Lunar Outpost Crew with Cargo DRM



DRM: Mars Exploration

- The Mars Exploration DRM employs conjunction-class missions, often referred to as long-stay missions, to minimize the exposure of the crew to the deep-space radiation and zero-gravity environment while, at the same time, maximizing the scientific return from the mission. This is accomplished by taking advantage of optimum alignment of Earth and Mars for both the outbound and return trajectories by varying the stay time on Mars. This approach allows the crew to transfer to and from Mars on relatively fast trajectories, on the order of 6 months, and allowing them to stay on the surface of Mars on the order of 18 months.



Mars Exploration DRM

Outline Countries Space Intentions

- **Background Information**
- **China**
  - China's Lunar Ambitions
  - China's Lunar History
  - China's Technology
- **Japan**
  - Japan's Lunar Intentions
  - Japan's Lunar Architecture
- **Europe**
  - Concurrent Design Facility lunar mission
  - Manned mission to the Moon
  - Mission Plan
  - Mission Hardware
- **India**
  - Introduction about ISRO
  - Current Program
  - Future Program

Difference Between the Environments of Earth and Space

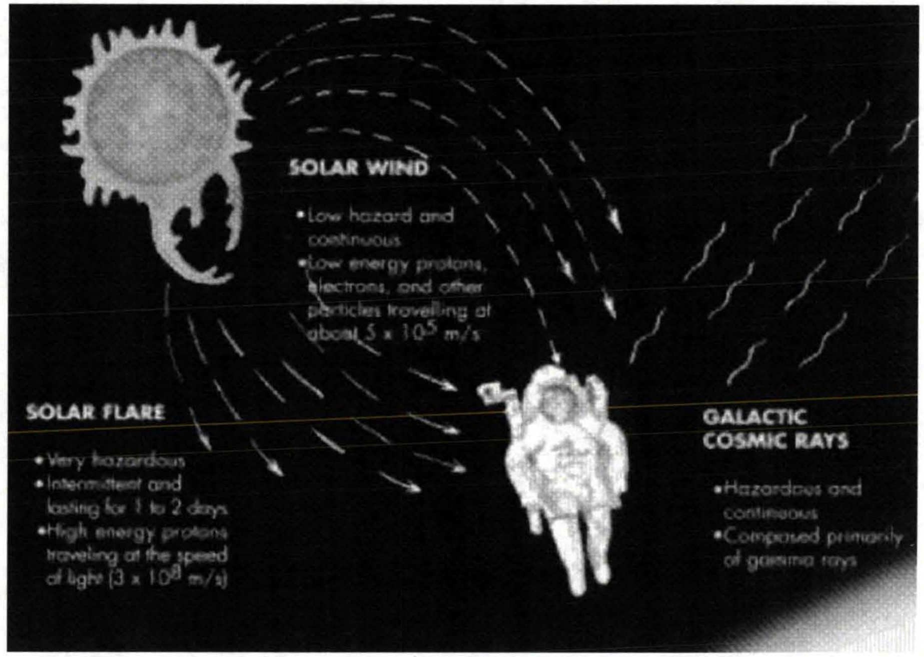
- **Space has no atmosphere, this means there is**
  - No pressure
  - Very little molecular activity
  - Extreme temperature variation
  - Radiation
    - Space doesn't have an atmospheric filter to help shield and protect humans from the danger of radiation exposure

Atmosphere

- **Atmospheres are the product of a number of complex and interacting processes:**
  - Radiation (solar, infrared, orbit, spin axis)
  - Chemistry (primordial composition, chemical interactions and mass exchange with solid planet, photochemistry)
  - Space Interactions (loss or gain of matter through impact, escape)
  - Thermodynamics (redistribution of materials due state changes, oceans, polar caps, condensate clouds)
  - Dynamics (redistribution of materials due to creation of kinetic energy by heat engine)
  - Biology (mass and energy cycling between non-living and living)

Space Radiation

- **Space radiation is different from the kinds of radiation we experience here on Earth, such as x-rays or gamma rays.**
  - Space radiation is comprised of atoms in which electrons have been stripped away as the atom accelerated in interstellar space to speeds approaching the speed of light – eventually, only the nucleus of the atom remains.
- **Space environment presents radiation conditions.**
  - It is not uniform.
  - It depends on parameters like altitude, geographic latitude and activity of the Sun.



Centripetal Force

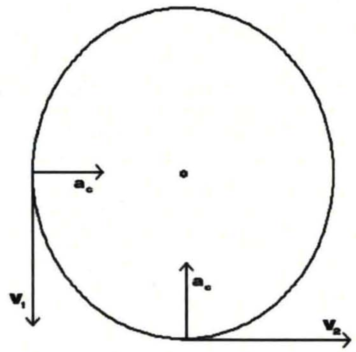
Centrifugal acceleration pulls an object toward the centre of the radial force.

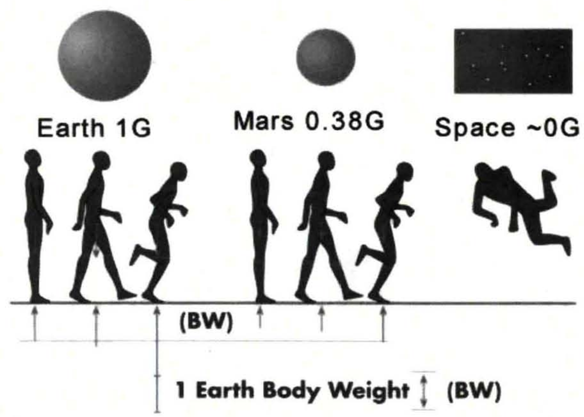
Centripetal Force is given by F= $\frac{m \times v^2}{r}$

Spacecraft orbiting Earth produce centrifugal acceleration that counterbalances Earth's gravitational acceleration.

$$F_g = F_c \qquad G_u \frac{Mm}{r^2} = \frac{m \times v^2}{r}$$

$$v = \sqrt{\frac{G_u \times M}{r}}$$





Escape Velocity depends only on radial distance, r

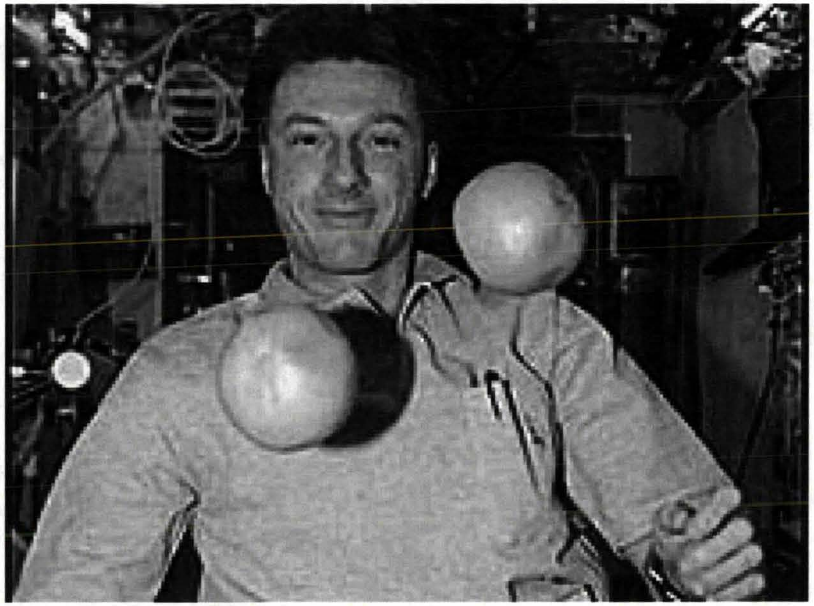
The spacecraft is "free" fall around Earth with the two opposing acceleration forces producing momentary resultant gravitational forces that range between 10^3 and 10^6 g

- **Martian Surface Gravity 3.72 m/sec²**
- **Lunar Surface Gravity 1.62 m/sec²**

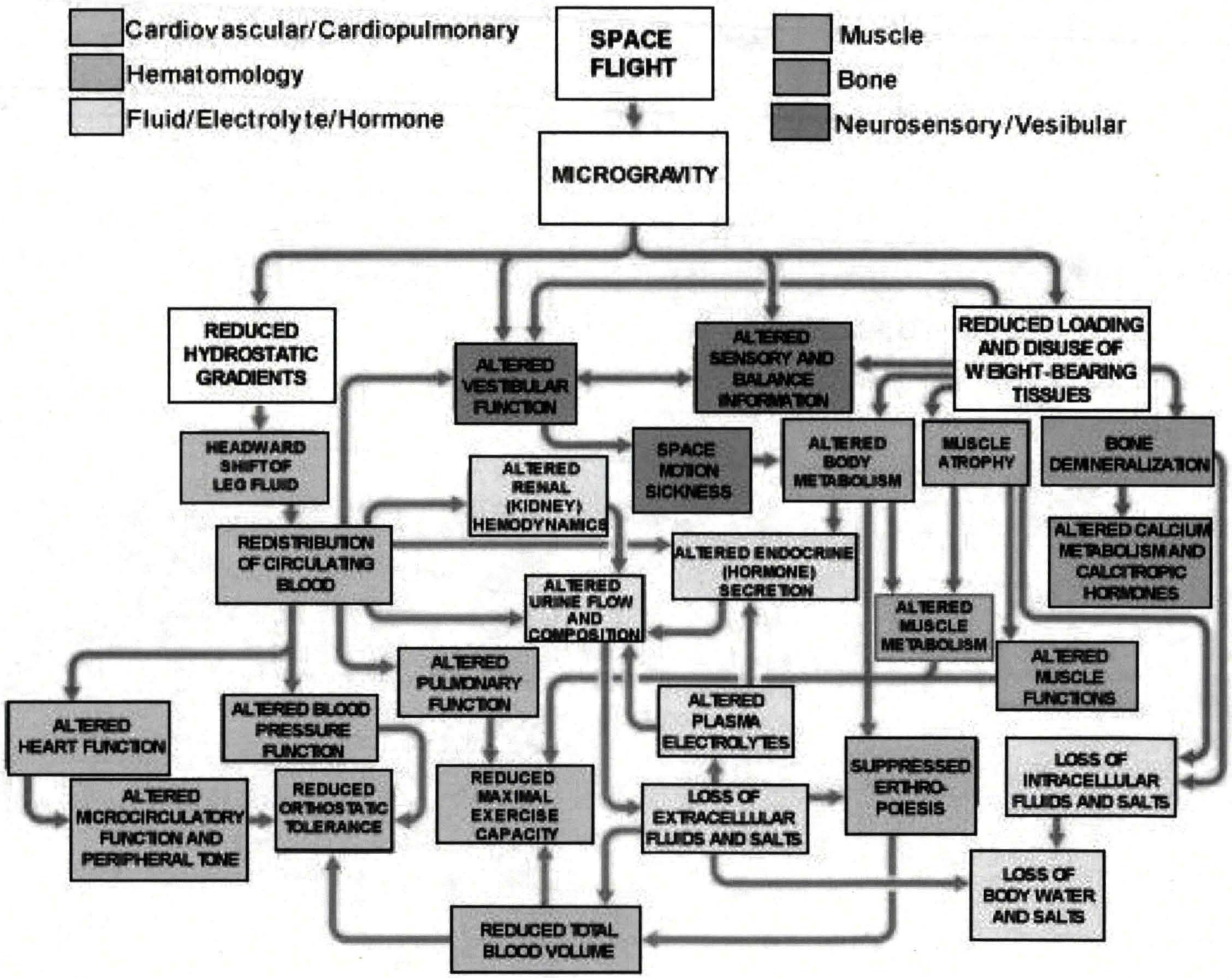
What Happens to Life When Gravity Changes?

- **Weight is a factor driving numerous chemical, biological and ecological processes on Earth.**
- **Growth, Development, Structure, Function, Orientation and Motion have all evolved features to cope with taking advantage of gravitational forces.**
- **The omnipresence of gravity has shaped the evolutionary process of all biologic system on Earth.**
- **Without gravity, there is**
  - NO 'falling down',
  - NO need for structural support,
  - NO convective mixing,
  - NO up and down,
  - NO separation of air and water,
  - Etc

- **Preparing for Zero Gravity**
- **Zero Gravity Water Bubble**



Conclusion - Different changes that occur in the body as a result of space flight



Habitability and environmental factors

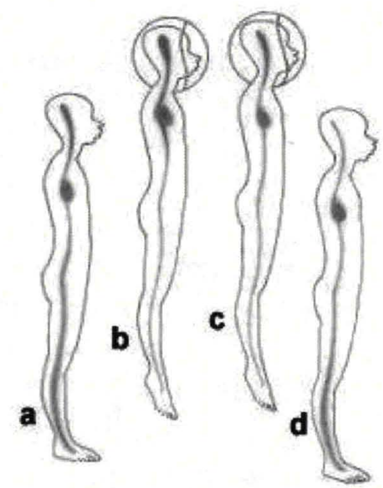
- **Advanced life support**
  - Inability to maintain Acceptable Atmosphere in Habitable area
  - Inability to Provide and Recover Potable Water
  - Inadequate Supplies adequately (including maintenance, emergency, provisions, and edible food)
  - Inability to Maintain Thermal Balance in Habitable Areas
  - Inability to Adequate Process Solid Wastes
  - Inadequate Stowage and Disposal Facilities for Solid and Liquid Trash Generated During Mission
  - Inadequate Nutrition (Malnutrition) Due to Inability to Provide and Maintain a Bio-regenerative System
- **Food and nutrition**
  - Inadequate Nutrition
  - Unsafe Food Systems
  - Difficulty of Rehabilitation Following Landing Due to Nutritional Deficiencies
  - Human Performance Failure Due to Nutritional Deficiencies

Human Adaptation and Countermeasures

- **Bone loss**
  - Acceleration of Age-Related Osteoporosis
  - Fracture & Impaired Fracture Healing
  - Injury to Soft Connective Tissue, Joint Cartilage, & Intervertebral Disc Rupture w/ or w/o Neurological Complications
  - Renal Stone Formation
- **Cardiovascular alterations**
  - Occurrence of Serious Cardiac Dysrhythmias
  - Impaired Response to Orthostatic Stress
  - Diminished Cardiac Function
  - Manifestation of Previously Asymptomatic Cardiovascular Disease
  - Impaired Cardiovascular Response to Exercise Stress
- **Human behavior and performance**
  - Human Performance Failure Because of Poor Psychosocial Adaption
  - Human Performance Failure Because of Sleep and Circadian Rhythm Problems
  - Human Performance Failure Because of Human System Interface Problems & Ineffective Habitat, Equipment, Design, Workload, or Inflight Information and Training Systems
  - Human Performance Failure Because of Neurobehavioral Dysfunction

Cardiopulmonary System

- **Heart rate remains lower during the normal daily activities of space flight compared to Earth-based conditions.**
- **The blood vessels serve as the communication line between all the body systems. Therefore, small changes in any of these body systems can have a "waterfall" effect that spreads and creates changes throughout the body.**
  - On Earth, gravity exerts a downward force to keep fluids flowing to the lower body. (a)
  - In space, the fluid tends to redistribute toward the chest and upper body. At this point, the body detects a "flood" in and around the heart. (b)
  - The body rids itself of this perceived "excess" fluid. The body functions with less fluid and the heart becomes smaller. (c)
  - Upon return to Earth, gravity again pulls the fluid downward, but there is not enough fluid to function normally on Earth. (d)



Psychological Aspects of Space Flight

A. Psychological, psychosocial and psycho-physiological	B. Environmental	C. Space system	D. Support measures
• Limits of performance (perceptual, motor) • Cognitive abilities • Decision-making motivation • Adaptability • Leadership productivity • Emotions/moods, attitudes • Fatigue (physical and mental) • Crew composition, crew compatibility • Psychological stability • Personality variables • Social skills • Human reliability (error rate) • Space adaption syndrome • Spatial illusions • Time compression	• Spacecraft habitability • Confinement • Physical isolation, social isolation • Weightlessness • Lack of privacy, artificial life support, noise • Work-Rest cycles • Shift changes • Desynchronization, simultaneous and / or sequential multiple stresses • Hazards • Boredom	• Mission duration and complexity • Organization for command and control, division of work, human/machine • Crew performance requirements, information load • Task load/speed crew composition • Space crew autonomy • Physical comfort/ quality of life, communications (intracrew and space-ground) • Competency requirements • Time compression	• In-flight psychosocial support • Recreation • Exercise selection criteria • Work-Rest/avoiding excess workloads, job rotation • Job enrichment, preflight environmental adaption training • Training for team effort • In-flight maintenance of proficiency • Cross-training • Recognition, awards, benefits • Ground contacts, self-control trainin

CLASS ASSIGNMENT 2

EVA Design Issues

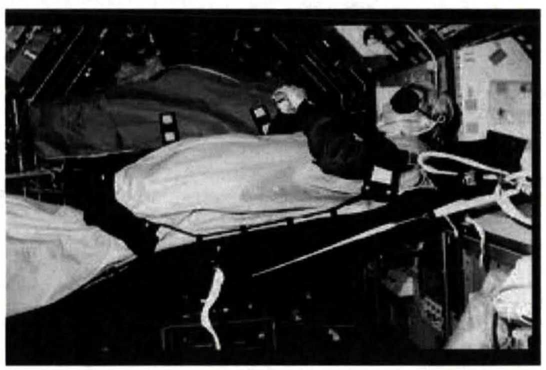
- **Consider walking in Space**
  - What are the issues one must consider?
    - Consider crew issues, technology issues, etc.
    - What could failures occur?
  - What differences would exist between EVA in zero gravity vs. on a surface (e.g., Mars/Moon)?
- **Prepare a 5-7 minute presentation on the issues and differences for class discussion**

- **Station crew spends their day working on:**
  - science experiments as well as monitoring those that are controlled from the ground.
  - medical experiments to determine how well their bodies are adjusting to living with no gravity.
- **However, there is no such thing as a typical day for an astronaut.**
- **An astronaut's work depends on their category:**
  - Commander (CDR)
  - Pilot (PLT)
  - Mission Specialist (MS)
  - Payload Specialist (PS)

Commander and Pilot

Payload Specialist

Sleeping in Space



Extreme Environments Habitat Design

System Engineering Design – Part I

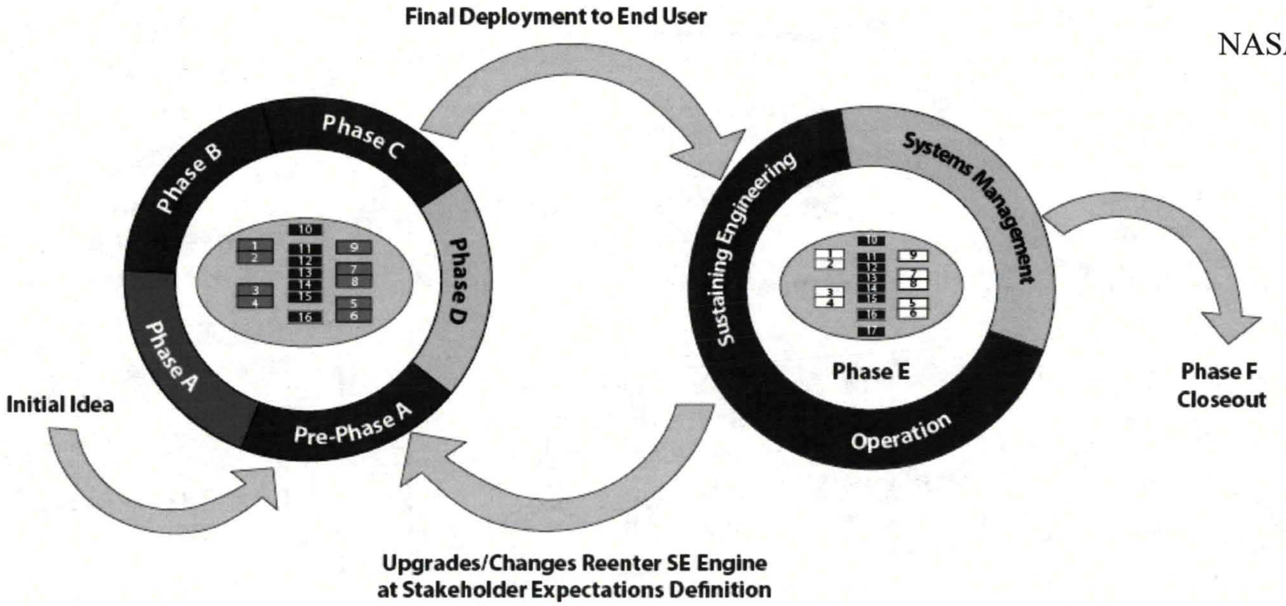
01. Space Operations Overview
NASA ESMD Capstone Design

Section Outline

- Quick overview of system engineering design process
- Major subsystem types in space systems
- Space support & protection concerns

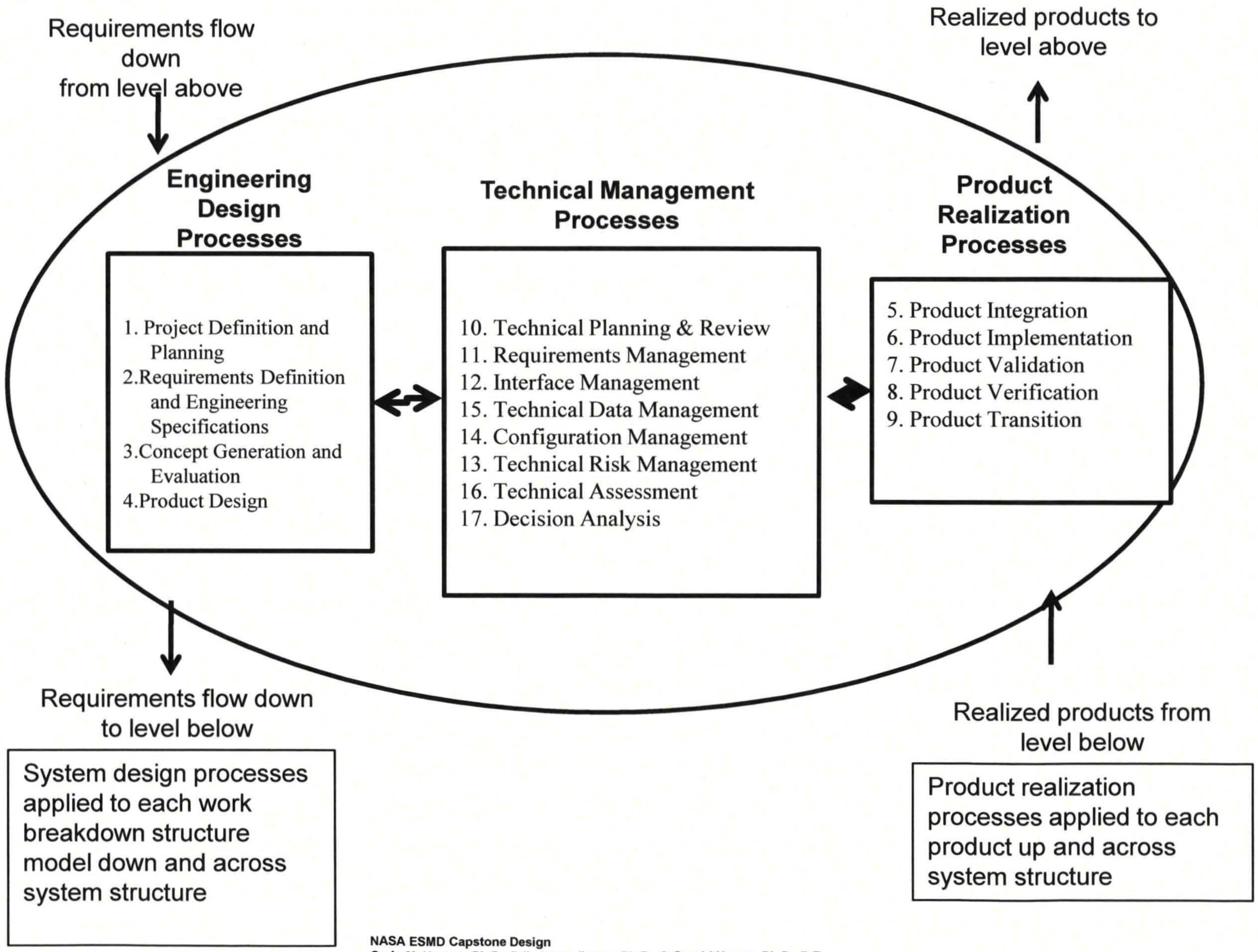
The Systems Engineering Life Cycle

NASA Handbook



- Pre-Phase A: Concept Studies. Mission objectives, Multiple system Requirements / Architecture / Concept of Operations (R/A/C)
- Phase A: Concept Development. Single system R/A/C & trade studies
- Phase B: Preliminary Design. To subsystem level R/A/C, interfacing, technology completion, verification plan
- Phase C: Design & Fabricate.
    - C(1): Final Design. Detailed design of all parts and components.
    - C(2): Fabrication. Fabricate / procure hardware, and code software.
- Phase D: System Assembly, Integration, Test, and Launch (SAITL)
    - D(1) – Verify components performance
    - D(2) - Integrate components and verify subsystems
    - D(3) – Integrate subsystems and verify system performance requirements
    - D(4) – System demonstration and validation
- Phase E: Operations
- Phase F: Closeout

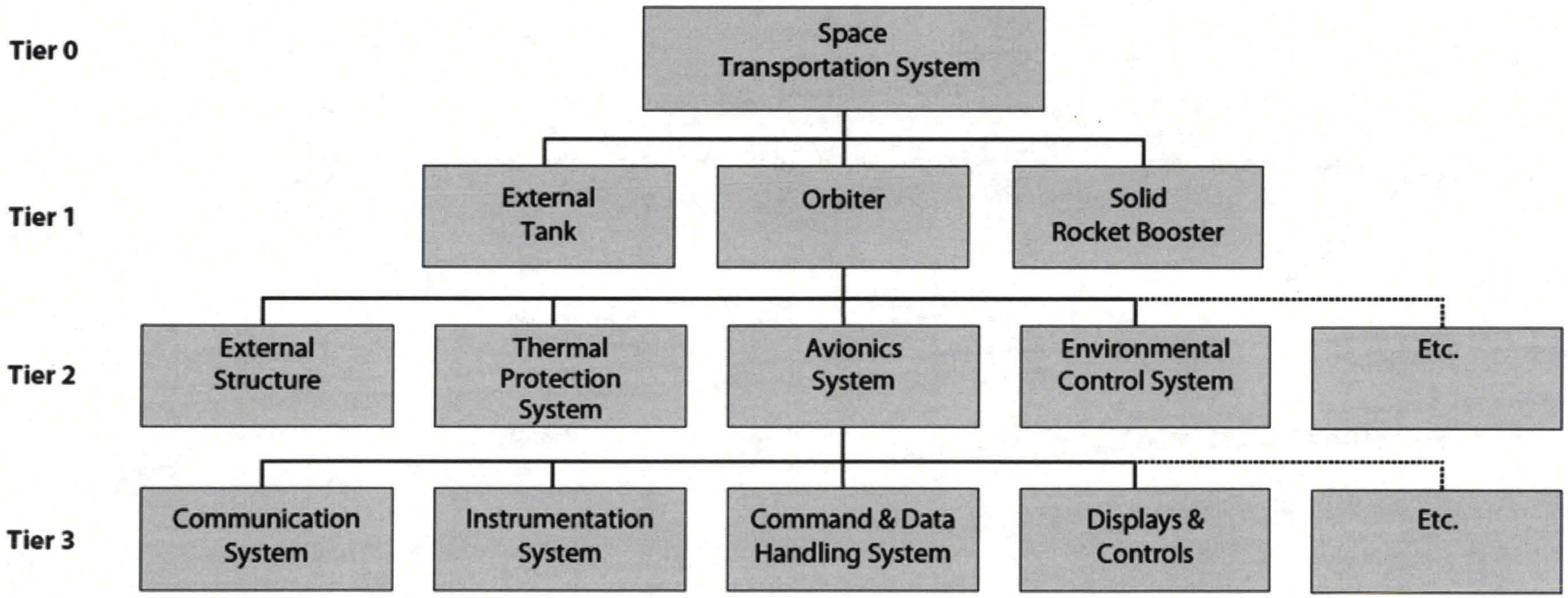
Systems Engineering Technical Processes



LSU

System Hierarchy

Example – partial view of first 3 tiers (typically 6 or more tiers) of a space transportation system:



Product hierarchy, NASA Handbook

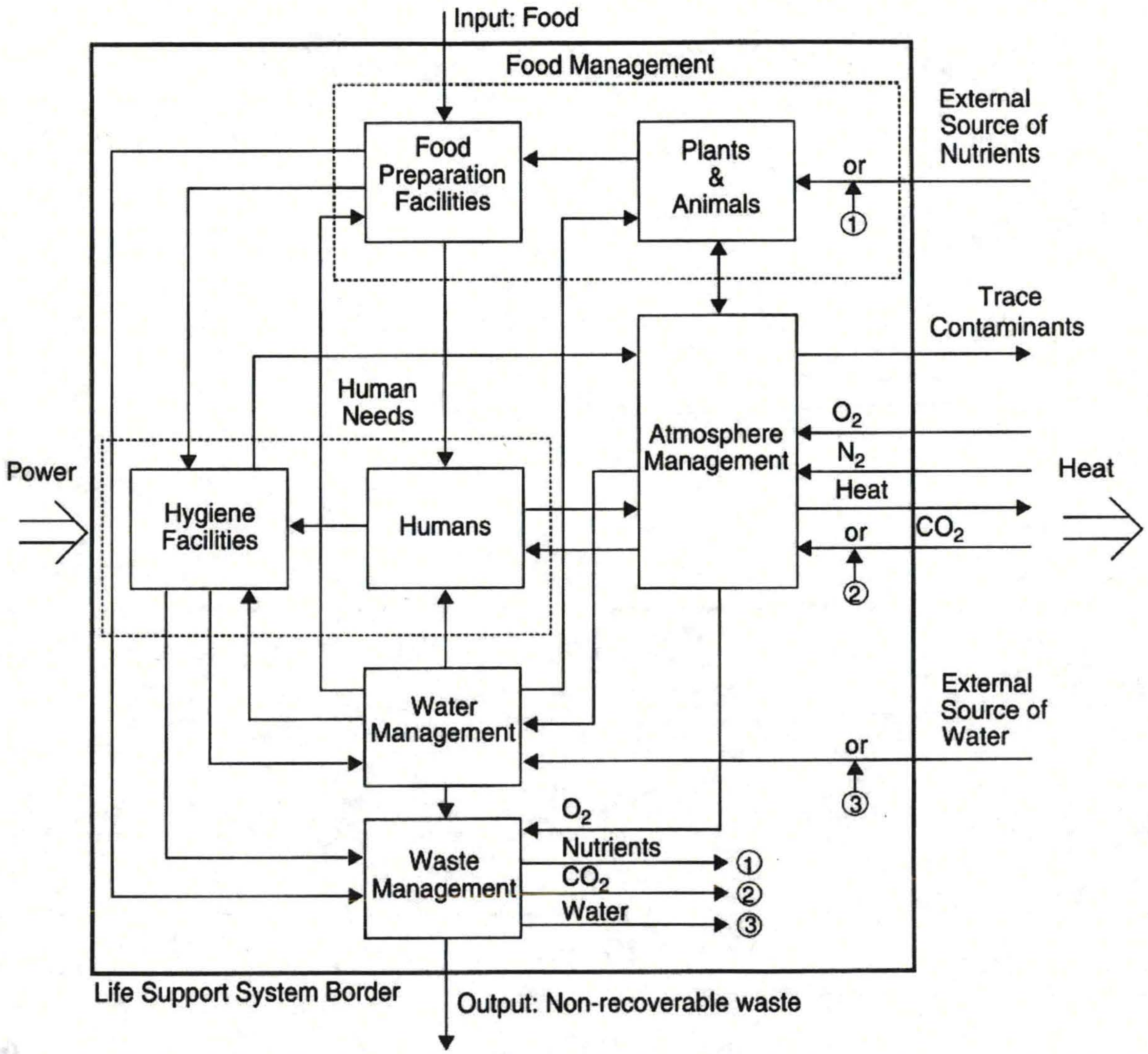
Power Subsystem

- For primary power, solar, nuclear and battery systems may be used.

Design Parameter	Photovoltaic	Solar Dynamic	Reactor	Radio-isotope
Power range (kW)	0.1–300	10–300	100–10,000	0.1–10
Specific power (W/kg)	25–250	9–15	2–40	5–20
Specific cost ($/W)	700–2500	1000–2000	400–700	16,000– 200,000
Radiation hardness	low-medium	high	very high	very high
Stability and maneuverability	low	medium	high	high
Low-orbit drag	high	high	medium	low
Storage	batteries	integral thermal	none	none
Shadowing sensitivity	high	high	none	none
Obstruction of view	high	high	medium	low
Safety reporting	minimal	minimal	high	medium
System availability	6–12 months	not commercial	not commercial	custom

Design Parameters for Common Systems to Supply Primary Power (Larson & Wertz 1993)

Life Support Subsystem



Life Support Functions and Relationships. Doll and Case 1990

Life Support System

- A large portion of the mission mass comes from the consumables. Food, water, oxygen, and nitrogen all need to be carefully calculated.
- Example: total mass and volume values for consumables for a long mission to Mars:

Consumables	Mass (lb)	Volume (liter)
Food (including packaging)	24393.6	31680
Water	14260.4	6480
Nitrogen	2325.8	1270
Water to produce Oxygen	9492.1	4310

In Situ Resource Utilization Systems

- In-Situ Resource Utilization
  - Resource Extraction
    - Resource Assessment
    - Resource Acquisition
    - Resource Beneficiation
    - Site Management
  - Material Handling & Transportation
    - Fixed Site Transportation
    - Mobile Material Transportation
    - Payload Material Handling
    - Cross Platform Capabilities, Reliability and Logistics
  - Resource Processing
    - Mission Consumable Production (Life Support & Propellant
    - Feedstock Production for In-Situ Manufacturing
    - Feedstock Production for Surface Construction
    - Common Critical Components
  - Surface Manufacturing with In-Situ Resources
    - Additive Manufacturing Techniques
    - Subtractive Manufacturing Technologies
    - Formative Manufacturing Technologies
    - Locally Integrated Energy Systems
    - Locally Integrated Systems & Components
    - Manufacturing Support Systems
  - Surface Construction
    - Site Planning
    - Surface & Subsurface Preparation
    - Structure/Habitat Fabrication
    - Radiation & Micro Meteoroid Debris Shielding
    - Structure & Site Maintenance
    - Landing & Launch Site
  - Surface ISRU Product & Consumable Storage and Distribution
    - Surface Cryogenic Fluid & Propellant Storage & Distribution
    - Chemical Reagent Storage & Distribution
    - Gas Storage & Distribution
    - Water & Earth Storable Fluid Storage & Distribution
    - Utility Connections & Interfaces
    - Hazard Detection & Suppression
  - ISRU Unique Development & Certification Capabilities
    - Modeling & Standards
    - Simulants
    - Unique Test Environments (1-g)
    - Reduced Gravity Test Environments

NASA Systems Engineering Handbook 2007

Extreme Environments Habitat Design

Habitat Requirements

01. Space Operations Overview
NASA ESMD Capstone Design

Habitat Requirements

- **Class Assignment**
- **Overview of Future Space Exploration Concepts**
  - Transfer, Entry, Landing and Ascent vehicles Review
- **Crew (& Payload) Accommodations**
- **Supporting Human Habitat**
- **Human Support**
- **Supportability**
- **Environmental Control & Life Support Systems (ECLSS)**
- **Closed vs. Open Loop and Regenerative vs. non-Regenerative Technologies**
- **Extravehicular Activity**
- **Example NASA Projects**

"We choose....to do [these] things,
not because they are easy, but because they are hard..."

John F. Kennedy
September 12, 1962

NASA ESMD Capstone Design
Craig M. Harvey, Ph.D., P.E., Laura Ikuma, Ph.D., & Gerald Knapp, Ph.D., P.E.

Considering Space Habitation – Many Factors require Consideration

- **Destination – where are you going?**
  - Moon ↔ Mars ↔ Libration Points ↔ Asteroids;
- **System Reusability – do we reuse or throw away?**
  - Expendable ↔ Reusable;
- **Architecture Focus – short duration flights or inhabit long term?**
  - Sorties ↔ Colonization;
- **Surface Mobility – walk or ride?**
  - Local ↔ Global;
- **Launch Vehicles (LVs) – existing technology or new technology?**
  - Existing ↔ New Heavy-Lift;
- **Transportation – how do we get there?**
  - Numerous stages and technologies traded;
- **LEO Assembly (low earth orbit) – build it in space or totally on the ground?**
  - None ↔ Extensive;
- **Transit Modes**
  - Zero-gravity ↔ Artificial-gravity;
- **Surface Power – how much energy will be needed?**
  - Solar ↔ Nuclear;
- **Crew Size – small exploratory crew or inhabiting**
  - 4 ↔ ?
- **In Situ Resource Utilization (ISRU) – bring everything or use material at the habitat?**
  - None ↔ Extensive.

NASA Integrated Program that Never Was

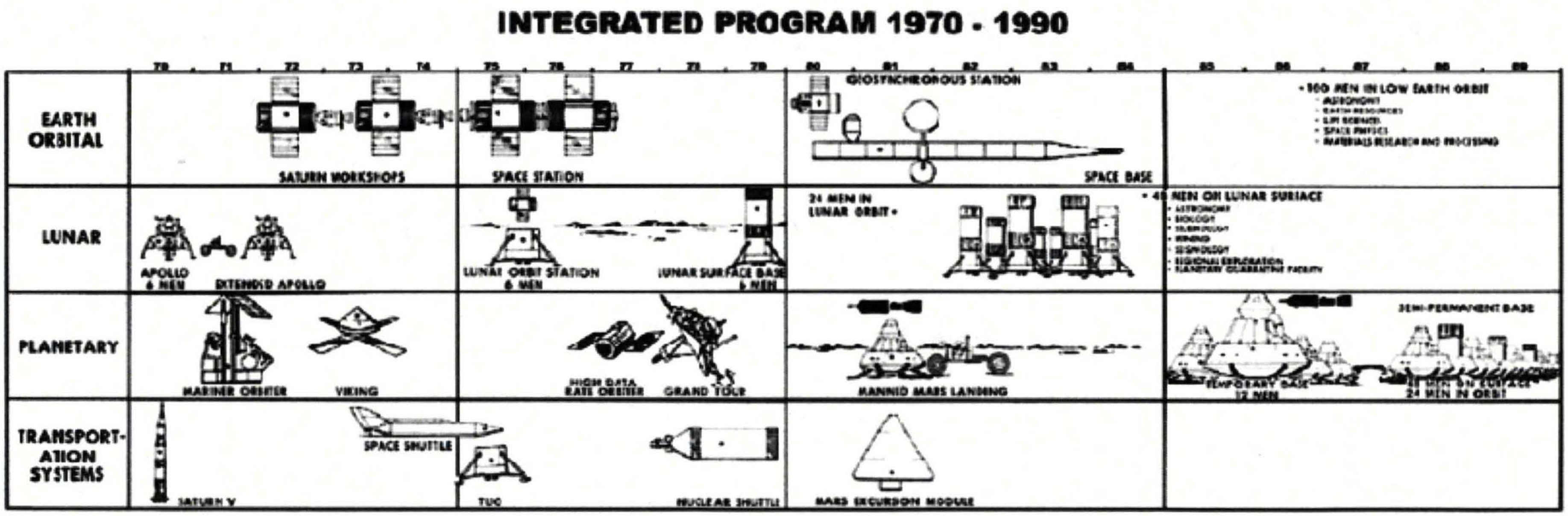


Figure 1-1. The integrated program that never was. The human spaceflight program that was expected to follow the initial Apollo lunar missions. Only a space shuttle and space station have been developed so far. Source: NASA

Potential Explorations

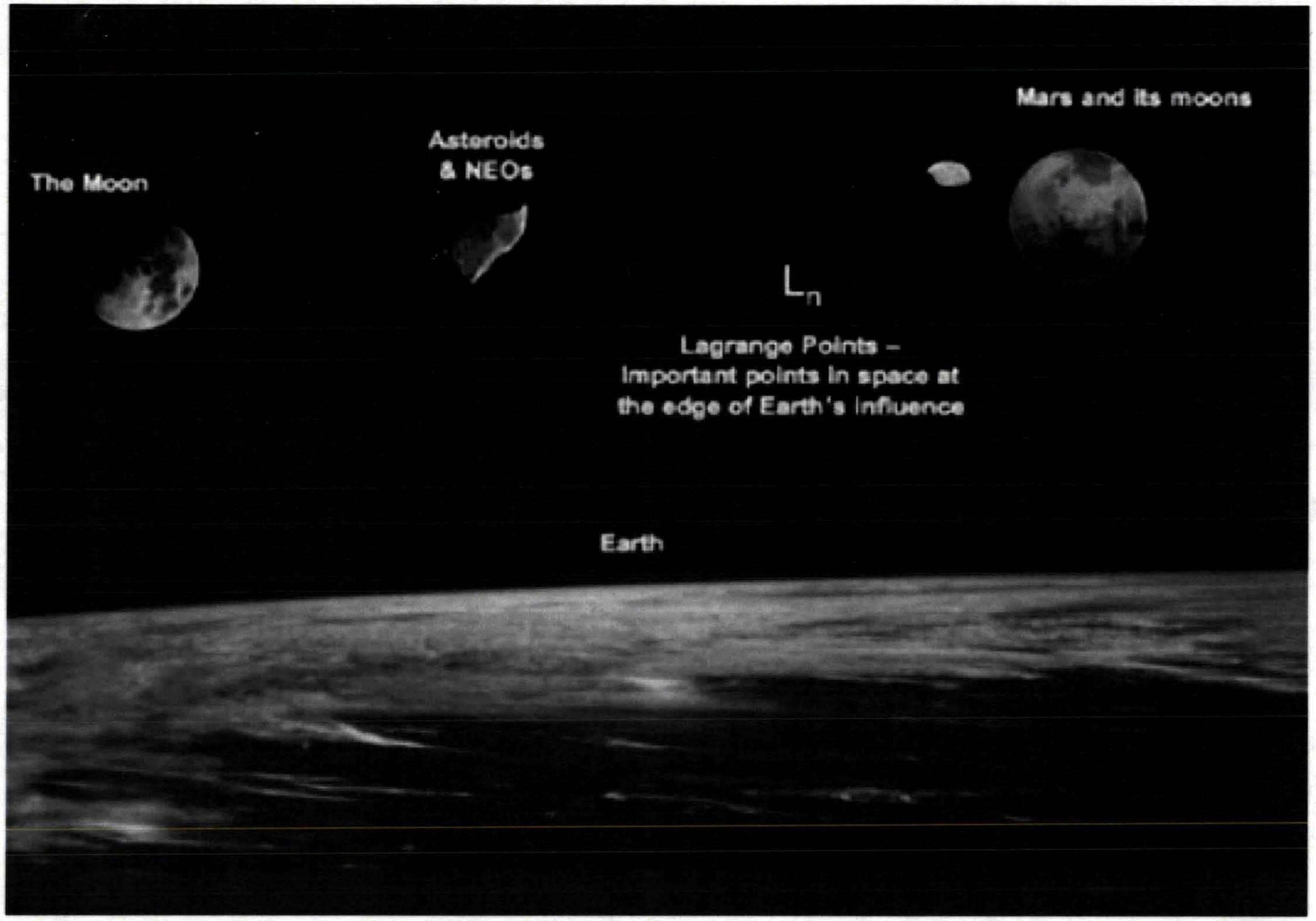


Figure 3.2-1. Potential destinations for the U.S. human spaceflight program. Source: Review of U.S. Human Spaceflight Plans Committee

Mars First Strategy

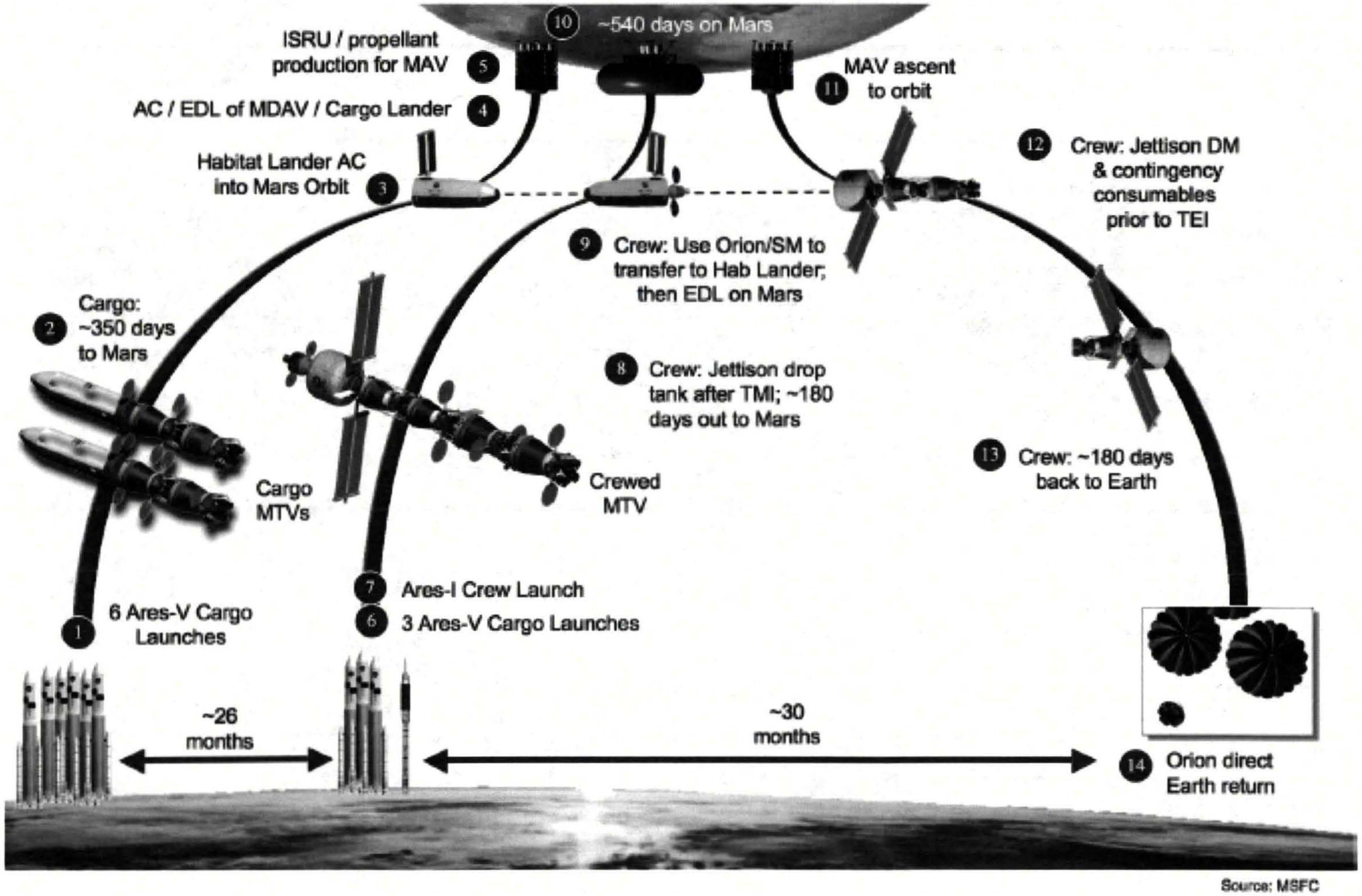


Figure 3.3.2-1. Architecture of the Mars First strategy, indicating the three missions launched toward Mars necessary to support the landing of a crew of six astronauts. Source: NASA

Timeline for Mars First Strategy

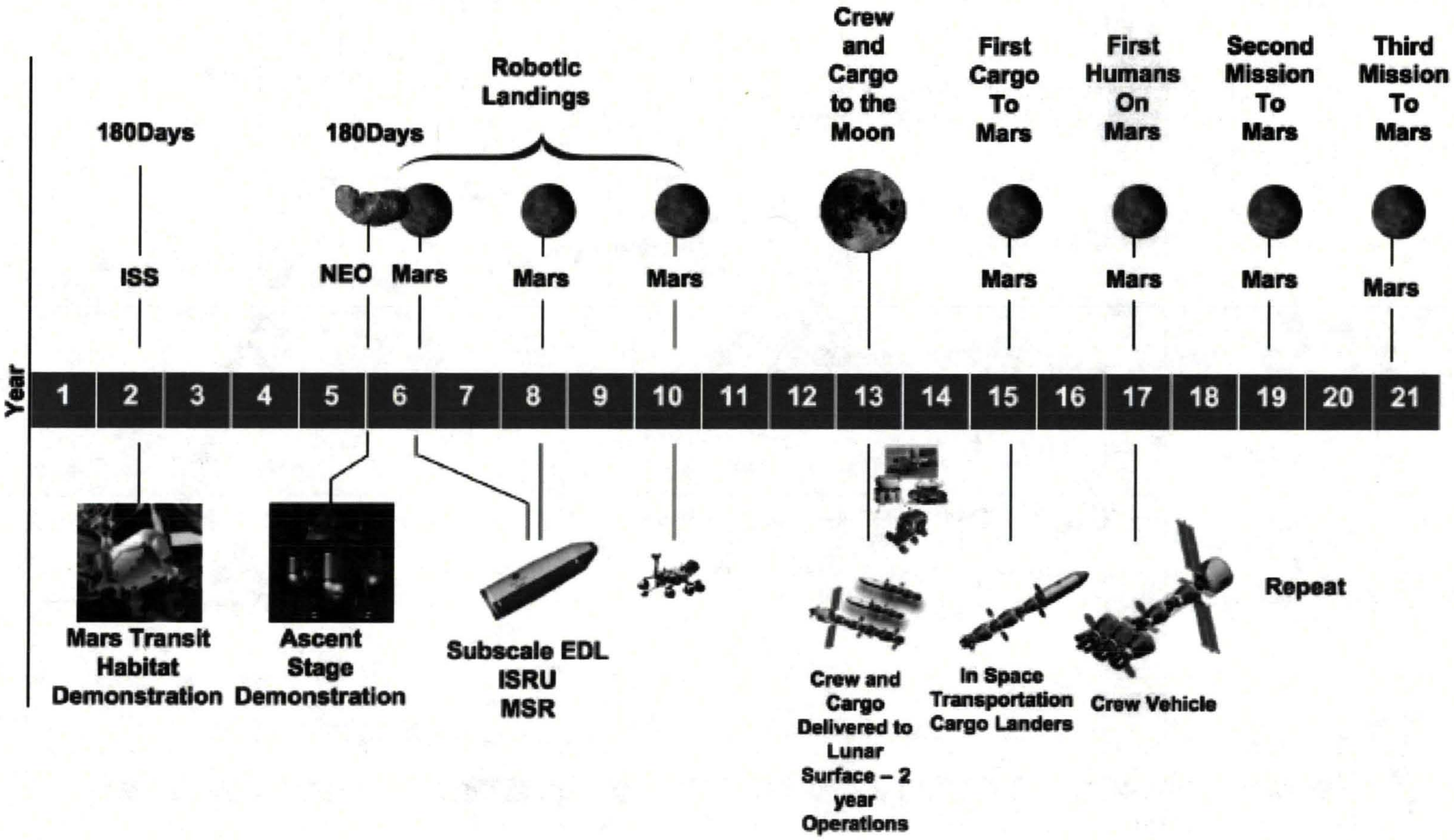


Figure 3.3.3-1. Timeline of milestones, destinations and capabilities of the Mars First strategy. Source: NASA

Moon First scenario

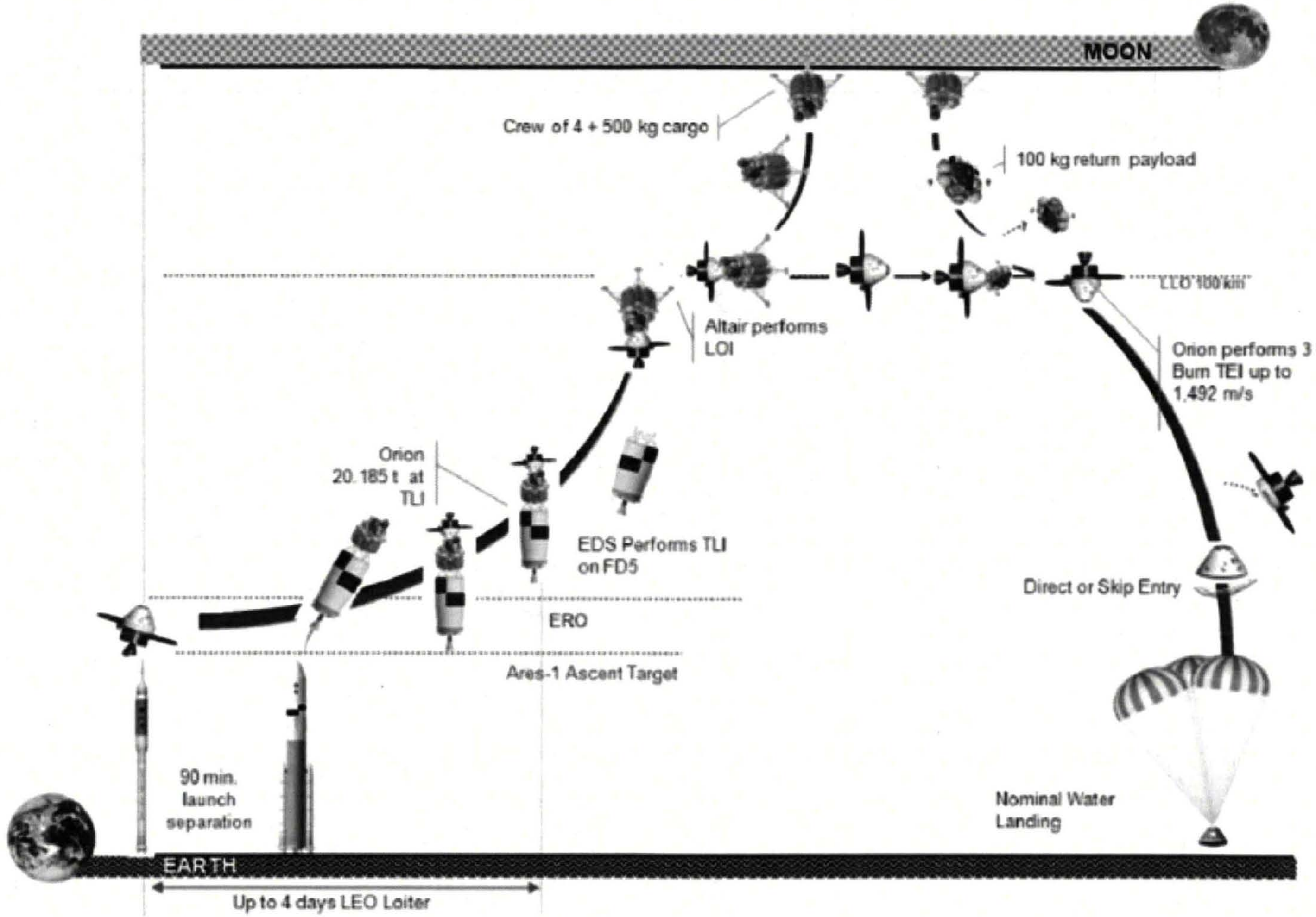


Figure 3.4.2-1. The architecture of the Moon First scenario, using Ares I and Ares V launchers. Source: NASA

Lunar Base timeline

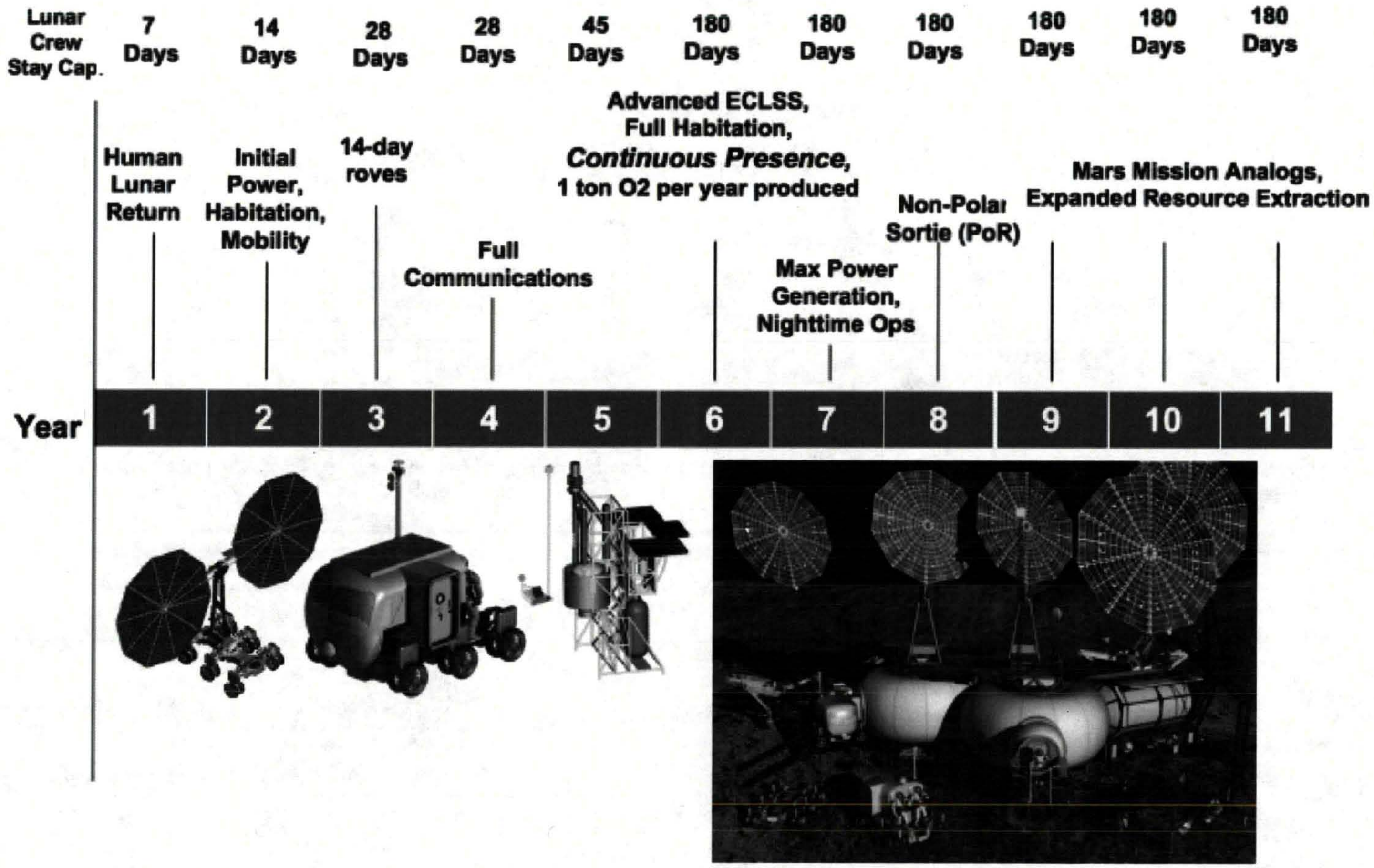


Figure 3.4.3-1. Timeline of milestones, destinations and capabilities of the Lunar Base variant of the Moon First strategy. Source: NASA

Flexible Path Options

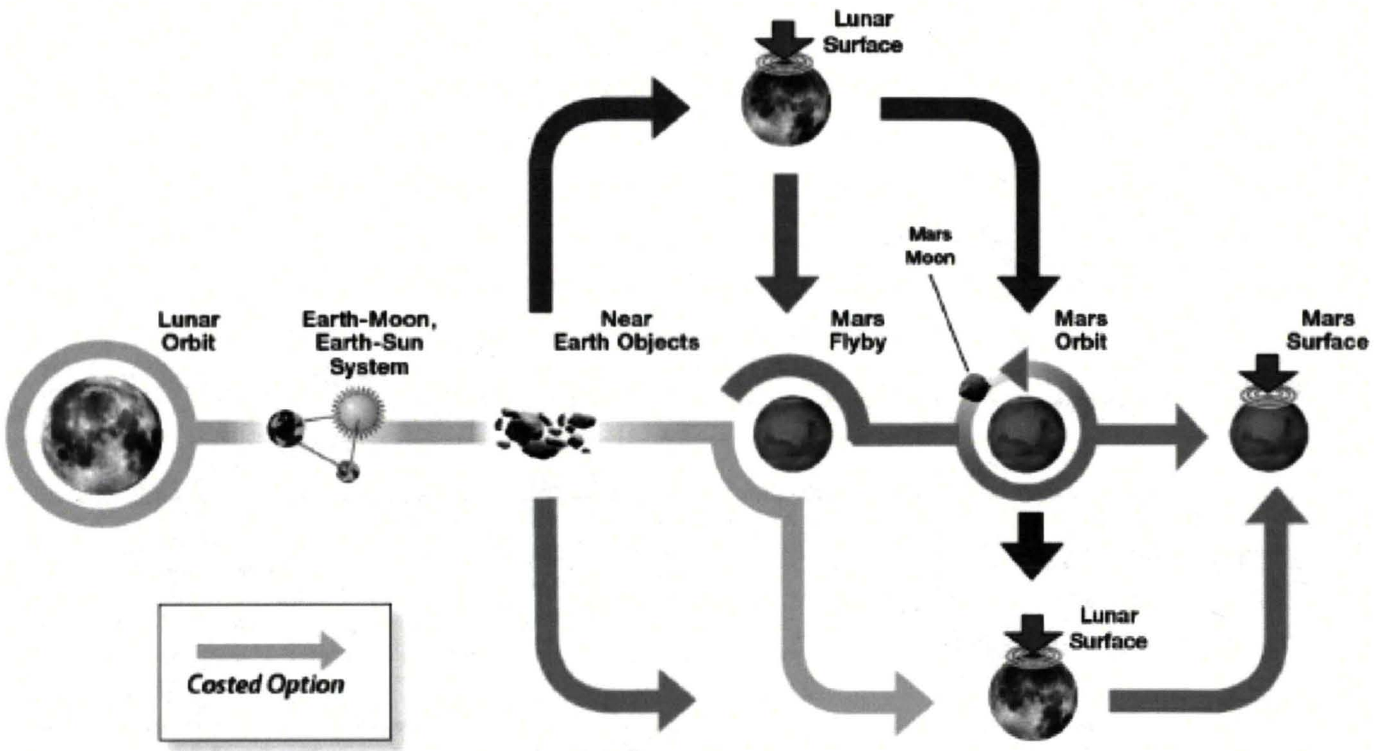
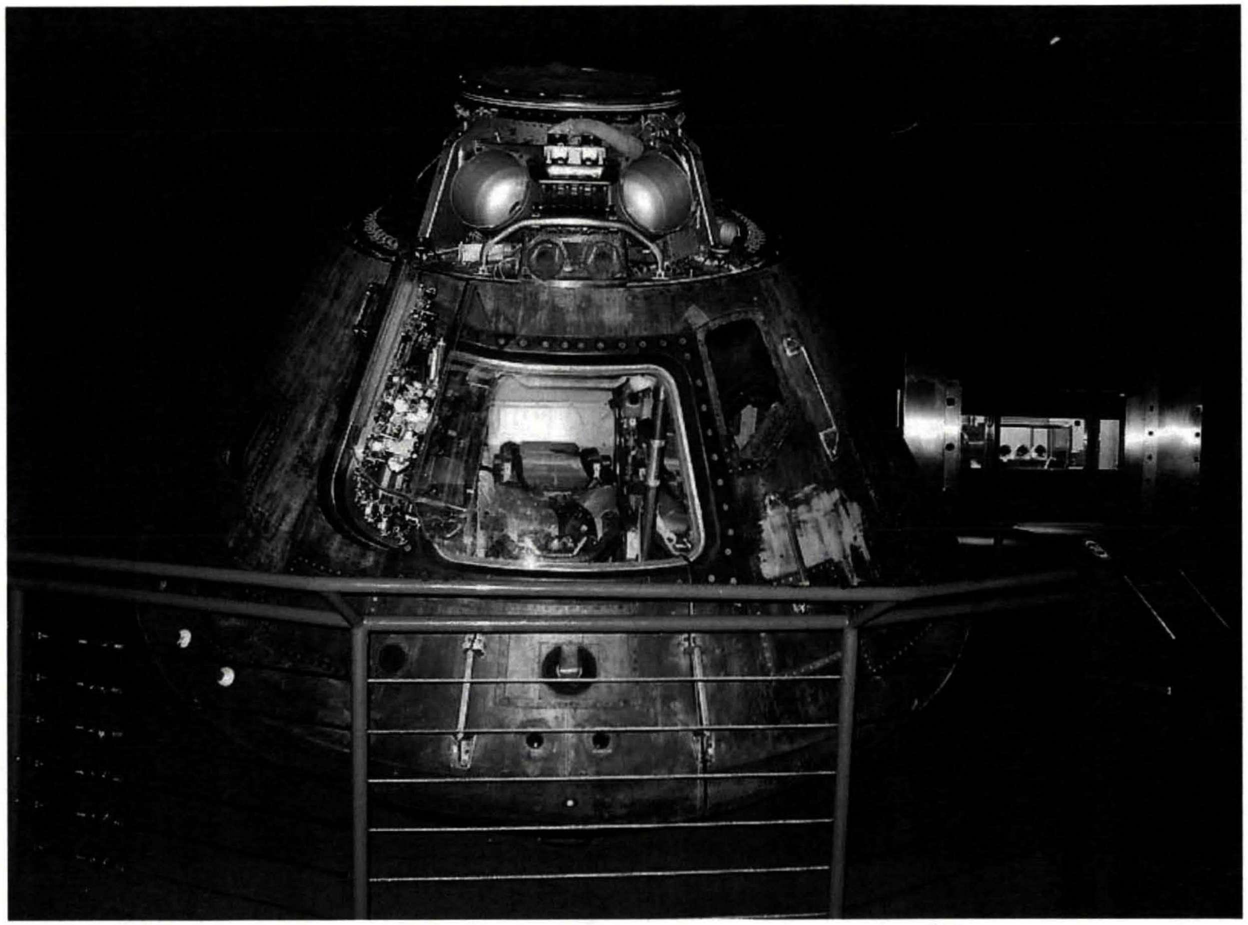


Figure 3.5.3-1. Options for exploration within Flexible Path strategy showing the main path toward Mars with alternatives to the Moon. Source: Review of U.S. Human Spaceflight Plans Committee

In-Class Assignments – Group Assignments

- **Assignment 1:**
  - Create a list of personal items you need to take with you on a 14 days trip.
    - This trip will be to a deserted island with no access to the modern conveniences of home.
- **Assignment 2:**
  - Design the packaging for your personal items including the shape, dimensions, material, weight, use, etc.
- **Assignment 3:**
  - Design the conceptual design layout of your transportation vehicle (e.g., seating, sleeping, restroom, control panels, etc). The vehicle will be about the size of a minivan interior. All surfaces are available including floor, walls, and roof.
  - You vehicle will have to accommodate 4-6 people for 14 days.
- **Assignment 4:**
  - Create a duty roster for your crew members while on your 14-day trip.
  - Think about what types of things should be done in route as well as during your stay. Roles will need to be assigned including driver (e.g., pilot), navigator, etc.

Apollo Capsule

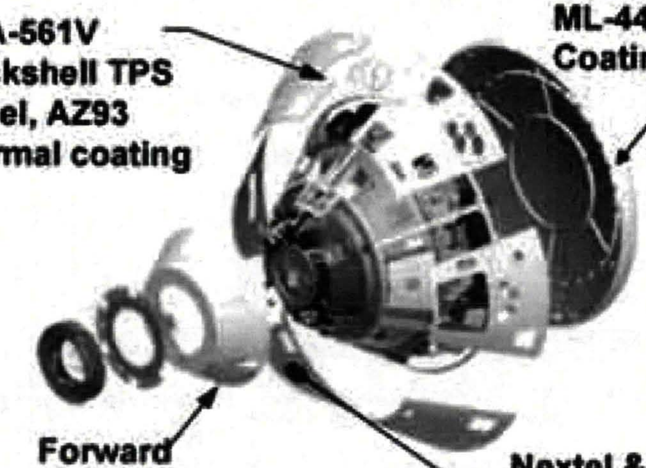


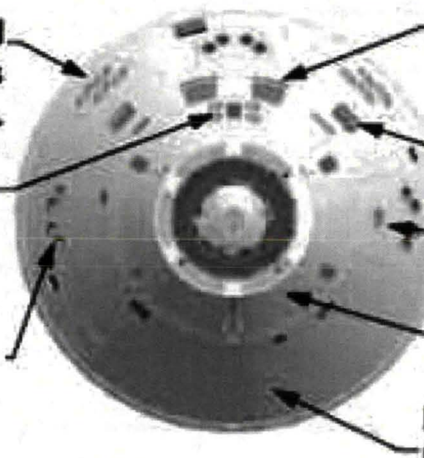
Crew Exploration Vehicle Project Office

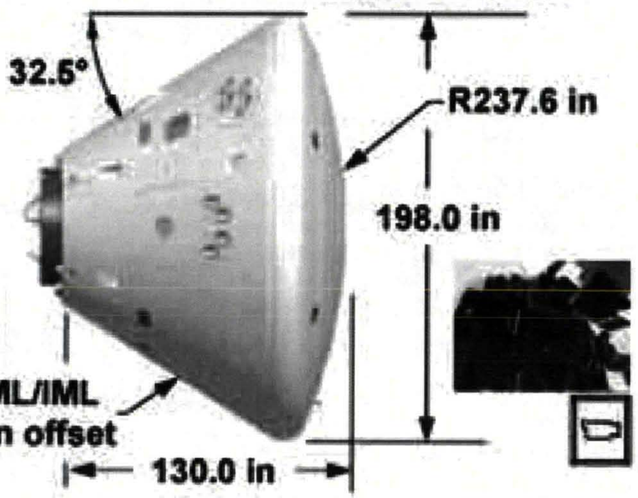
CEV Crew Module

Configuration Summary	
Diameter	16.5 ft
Ref Hypersonic Lift to Drag Ratio	.34 @ 157°α
Pressurized Volume (Total)	691.8 ft^3
Habitable Volume (Net)	361 ft^3
Habitable Volume per 4 CM	90.3 ft^3
CM Propellant	GO_2/GCH_4
Total CM Delta V	164 ft/s
RCS Engine Thrust	100 lbf
Lunar Return Payload	220 lbs

Mass Properties Summary	
Dry Mass	17396.8 lbs
Propellant Mass	385.1 lbs
Oxygen / Nitrogen Mass / Water	282.8 lbs
CM Landing Wt.	16174.3 lbs
GLOW	18706.3 lbs







Modeling and Simulation

- **NASA's Design Visualizations Group created simulations to support the CxP Preliminary Design Review (PDR). The videos were created from simulations using the CAD models of GSE, facilities and spacecraft designed at KSC and other Centers. The simulations were used by subject matter experts (SMEs) to determine how to safely and efficiently process the Orion and Ares for launch.**
  - Overall Flow: http://www.youtube.com/watch?v=BwNpoSvpA6Q
  - Orion Offline Operations: http://www.youtube.com/watch?v=GcpETT-A3X0&feature=related
  - RSRM Offline: http://www.youtube.com/watch?v=xG1fkbu8SNY&feature=channel
  - VAB Operations: http://www.youtube.com/watch?v=dfo-J3AxCw8&feature=channel
  - Launch Pad Ops: http://www.youtube.com/watch?v=nDSgz5G3jgc&feature=channel
  - Orion Recovery: http://www.youtube.com/watch?v=Nzylif7ZQBY&feature=channel

Human Support

- **Radiation- CEV**
  - Assumed a 7-day mission length (Table 4.5, 4 SPEs)
  - Risk calculated on four SPE (solar flares, 1972/1989 baselines)

Table 4-5. Analysis Cycle 2 Radiation Dose Calculations for Aluminum CEV with HDPE Supplemental Shielding

Organ Dose 4× 1972 SPE	Apollo	Aluminum CEV*		CEV + Poly 5 g/cm²	
Skin (Gy-Eq)	10.36	42.63	47.75	12.25	13.72
Eye (Gy-Eq)	8.20	32.54	36.44	9.71	10.87
BFO (Gy-Eq)	1.39	4.17	4.67	1.56	1.73
Organ Dose 4× 1989 SPE		**Aluminum CEV***		**CEV + Poly 5 g/cm²**	
Skin (Gy-Eq)		23.40	25.98	7.10	7.88
Eye (Gy-Eq)		16.57	18.39	5.42	6.01
BFO (Gy-Eq)		2.73	3.03	1.29	1.40

Note: Two columns for CEV represent two locations within vehicle.

Table 4-6. Excess Lifetime Cancer Risk for Shielded and Unshielded CEV as a Function of Crew Member Age and Gender

4× 1972 – Equivalent Solar Proton Event – CEV				
Organ Dose	Aluminum CEV		Vehicle + Poly 5 g/cm²	
Crew Characteristic	%Risk	95% C.I.	%Risk	95% C.I.
Male 35-yr	9.7	[3.4, 17.5]	1.7	[0.5, 4.7]
Male 45-yr	7.5	[2.7, 16.4]	1.3	[0.4, 3.5]
Female 35-yr	12.1	[4.0, 17.6]	2.1	[0.7, 5.9]
Female 45-yr	9.1	[3.2, 17.3]	1.5	[0.5, 4.3]
4× 1989 – Equivalent Solar Proton Event – CEV				
Organ Dose	Aluminum CEV		Vehicle + Poly 5 g/cm²	
Crew Characteristic	%Risk	95% C.I.	%Risk	95% C.I.
Male 35-yr	6.9	[2.4, 15.8]	2.2	[0.73, 6.0]
Male 45-yr	5.3	[1.9, 13.4]	1.7	[0.57, 4.5]
Female 35-yr	8.6	[2.9, 17.1]	2.8	[0.9, 7.6]
Female 45-yr	6.4	[2.3, 15.3]	2.0	[0.7, 5.6]

C.I. = Confidence Interval

LSU

- **Supporting the Human System**
  - Basic requirements to keep people alive in space
    - Oxygen – at right pressure
    - Water – for drinking, hygiene and humidity
    - Food
    - Waste Management

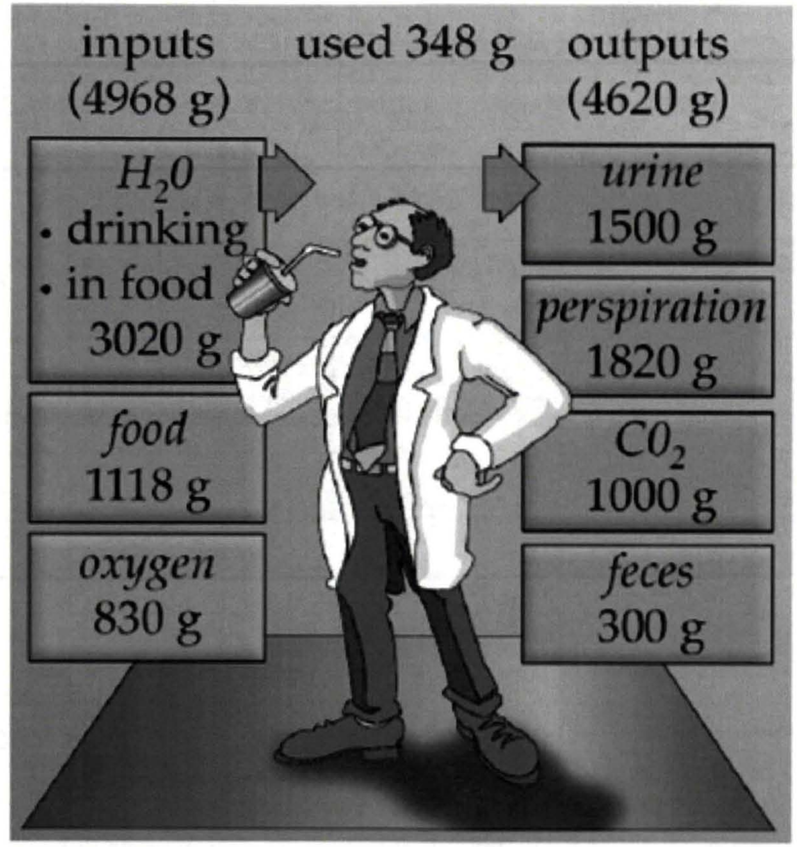


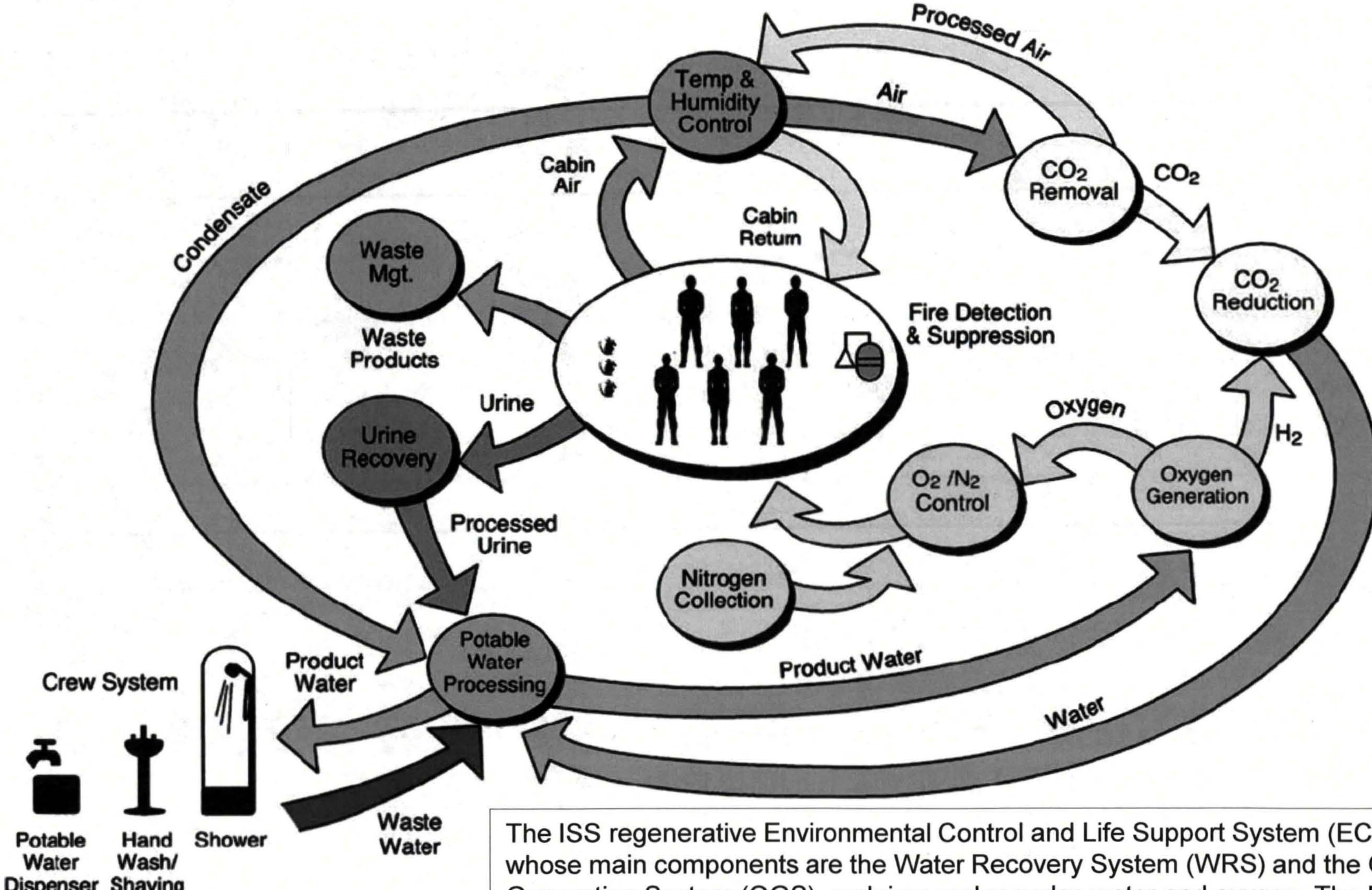
Figure 4.4.1-15. The Human System. Similar to any other system, humans take some amount of input, process it, and produce output. Here we see the approximate daily food, water, and oxygen requirements for an astronaut and the corresponding urine, perspiration, CO_2, and feces produced. (Adapted from Nicogossian, et al and Chang, et al)

Environmental Control & Life Support Systems (ECLSS)

- **Oxygen**
  - We breath at 14.7 psi (101kPa)
    - 20.9% - O2
    - 78.0% - N2
    - 0.04% - CO2
    - Trace gases like argon
  - What is right?
    - 14.7 psi @ sea-level
    - 2.0 psi @ 6520 ft
    - Can not be too O2 rich because it is toxic and can lead to disaster
    - Shuttle – 14.7 psi
      - Crews O2 10.2 psi 12-hours before EVA & breath O2 for 3-4 hours to prevent bends.
  - Closed loop control system to ensure no health hazard

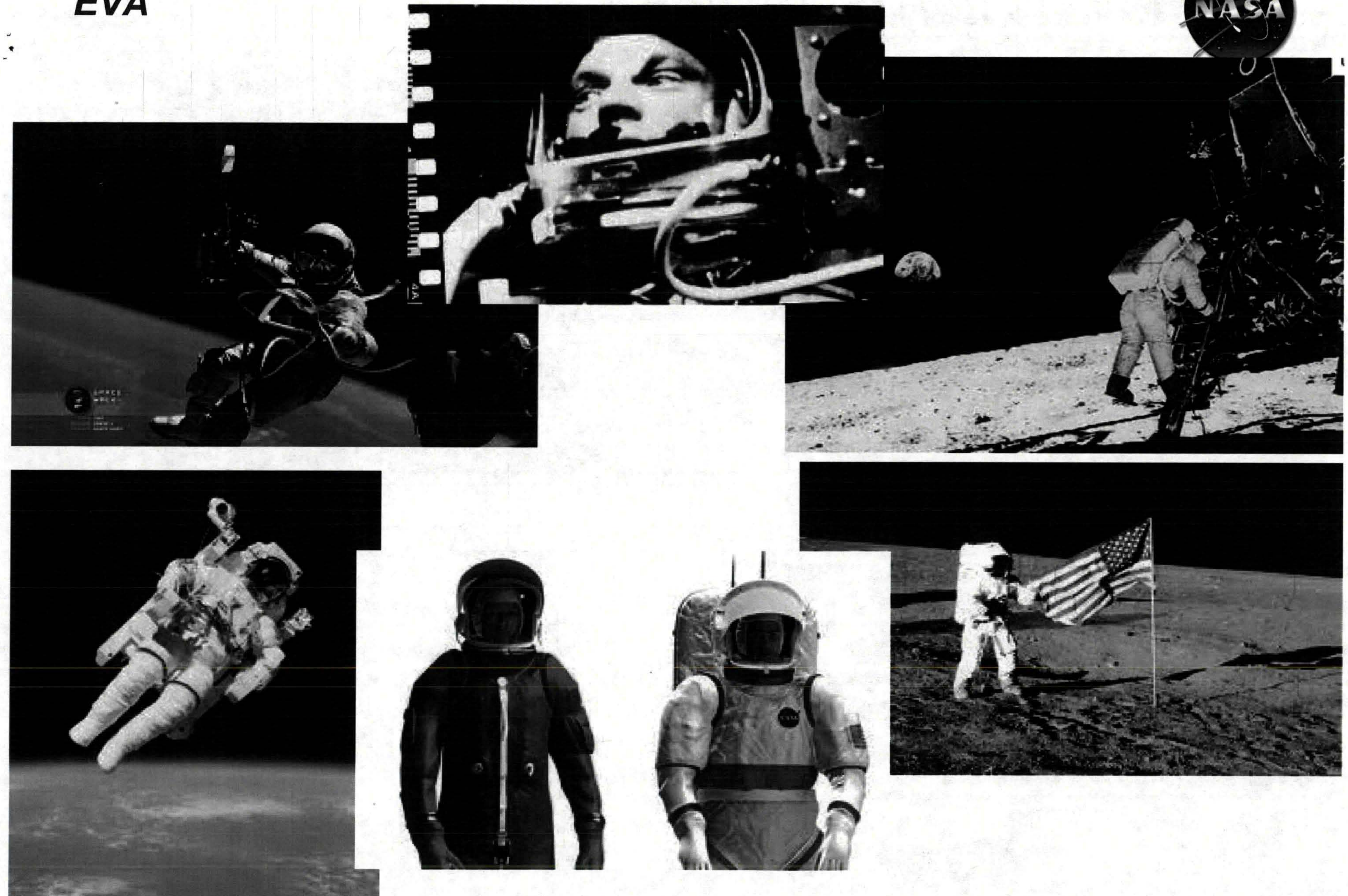
Figure 4.4.1-16. Apollo 1 Disaster. The Apollo 1 fire that claimed the life of astronauts Grissom, White, and Chaffee, was caused by the use of a pure oxygen environment inside the capsule. *(Courtesy of NASA/Johnson Space Center)*

ISS Flow of Resources - ECLSS



The ISS regenerative Environmental Control and Life Support System (ECLSS), whose main components are the Water Recovery System (WRS) and the Oxygen Generation System (OGS), reclaims and recycles water and oxygen. The ECLSS maintains a pressurized habitation environment, provides water recovery and storage, maintains and provides fire detection/suppression, and provides breathable air and a comfortable atmosphere in which to live and work within the ISS.

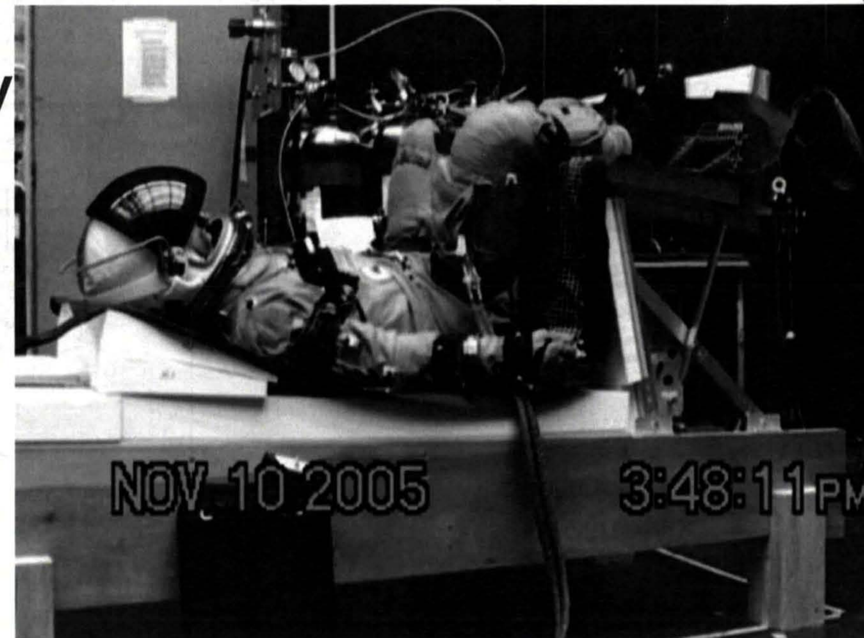
EVA

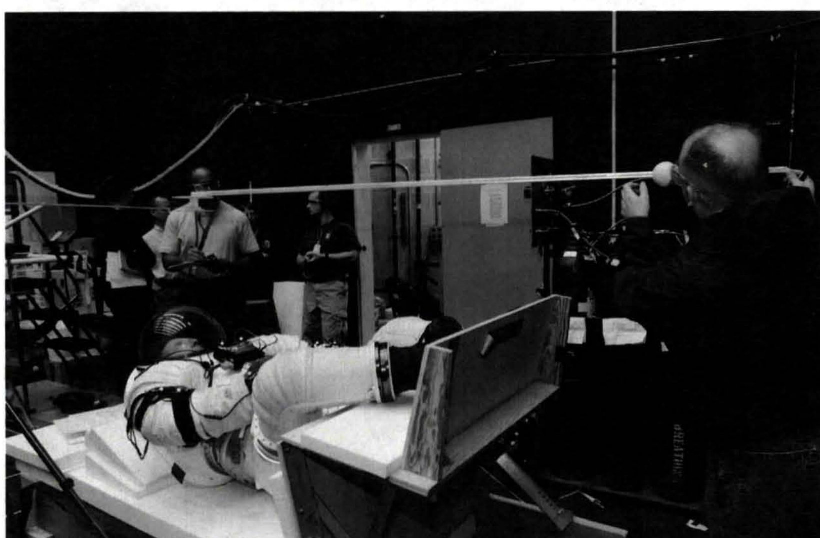


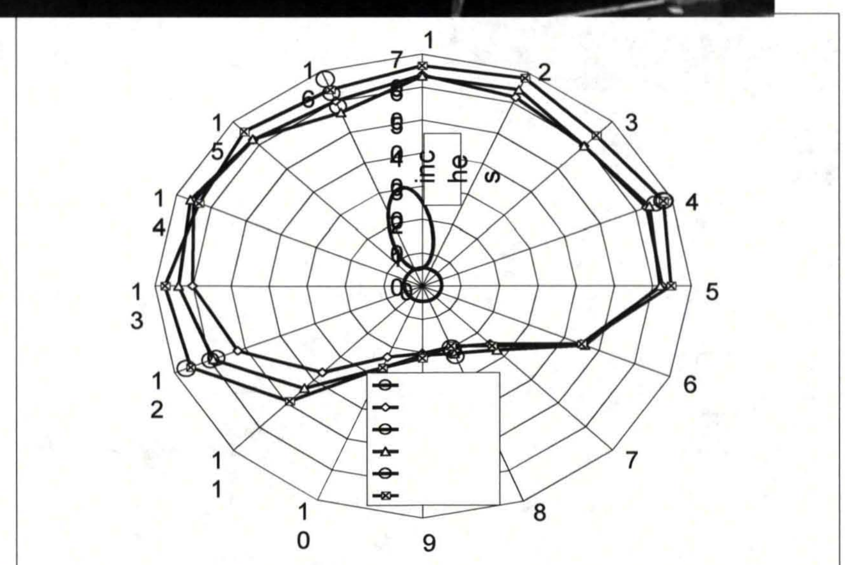
NASA ESMD Capstone Design
Craig M. Harvey, Ph.D., P.E., Laura Ikuma, Ph.D., & Gerald Knapp, Ph.D., P.E.

EVA Projects for Requirements Definition

- **Space Suit Comfort/Visibility**







stone Design
Ph.D., P.E., Laura Ikuma, Ph.D., & Gerald Knapp, Ph.D., P.E.

Extreme Environments
Habitat Design

Habitat Design: Human Factors

01. Space Operations Overview
NASA ESMD Capstone Design

Topics: Habitat Design

1. Human factors in habitat layout (discussion)
2. Biomechanics
3. Work physiology
4. Anthropometry
5. Safety
6. Augmented reality and situation awareness
7. Supervisory control systems
8. Other technology and issues

2.1 Biomechanics: Determining forces on the body

- **Strength demands, effects on the body**
- **Static models (strain on the back, shoulders, knees, etc.)**
- **Conditions for an object to remain at rest (or continue traveling at a constant velocity in dynamic equilibrium)**
  - All motions of a rigid body can be separated into translational motions and rotational motions.
  - Translational equilibrium: $\sum$ Forces = 0
  - Rotational equilibrium: $\sum$ Moments = 0
- **How will this change in extreme environments?**
  - Gravity may not be the same!

Biomechanics: Useful Tables

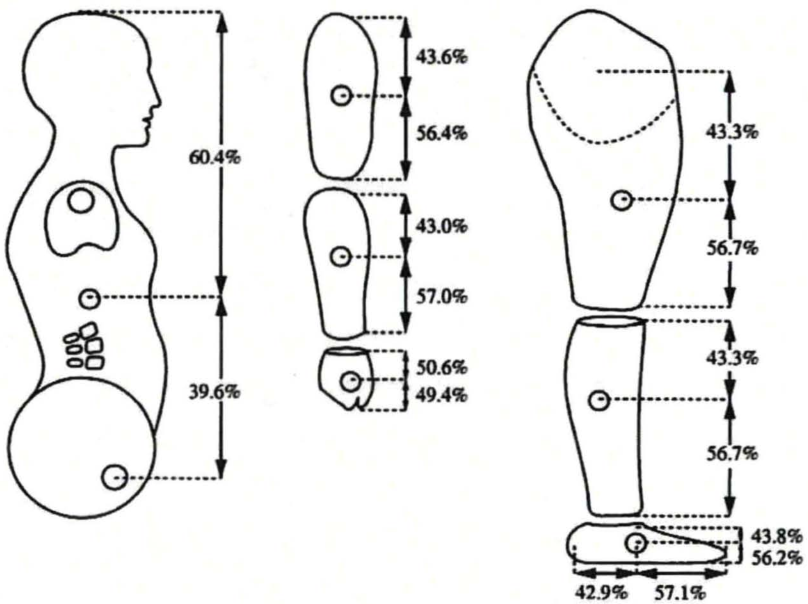


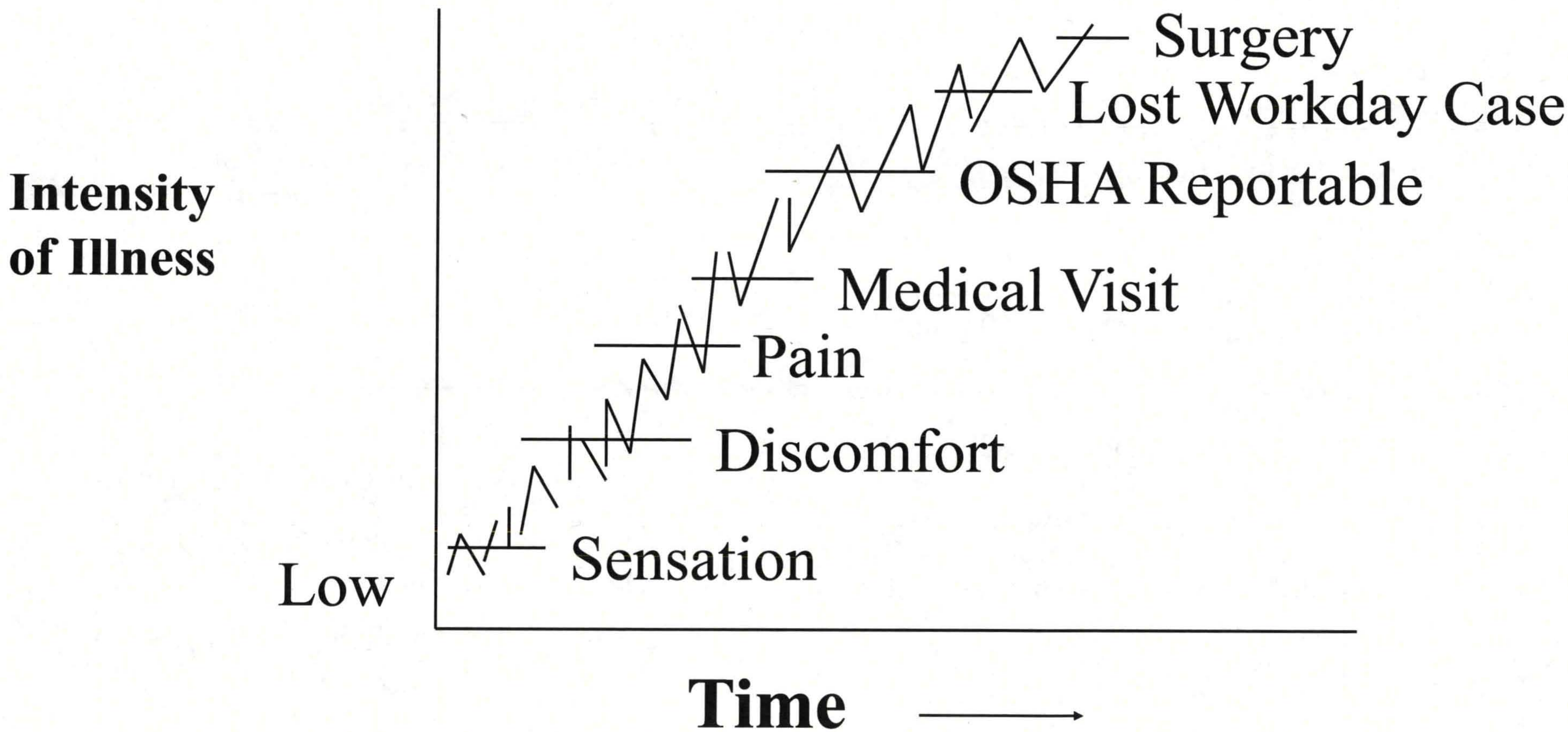
Fig. 4.3 The locations of centers of mass in the body segments in the sagittal plane indicated by percentages of the body segments. Adapted from Dempster (1955).

Table 4.4 Masses of body segments as a percentage of the whole body mass

Group body segments as a percentage of	Total body mass (%)	Individual body segment mass as a percentage of	Group segment mass (%)	Total body mass (%)
Head and neck	8.4	Head	73.8	6.2
		Neck	26.2	2.2
Torso (trunk)	50.0	Thorax	43.8	21.9
		Lumbar	29.4	14.7
		Pelvis	26.8	13.4
Each arm (total)	5.1	Upper arm	54.9	2.8
		Forearm	33.3	1.7
		Hand	11.8	0.6
Each leg (total)	15.7	Thigh	63.7	10.0
		Lower leg (shank)	27.4	4.3
		Foot	8.9	1.4

From: Tayyari and Smith (1997). Occupational Ergonomics Principals and Applications. Chapman & Hall: London, pp. 56-57.

Symptoms increase over time



Occupational causes of WMSDs

- **Neck**
  - Prolonged static, restricted posture
  - Prolonged lifting of the head
- **Back**
  - Prolonged static load on the upper torso musculature
  - Awkward posture: extensive trunk flexion or extension
  - Constant lifting from the floor
- **Shoulders**
  - Prolonged flexion/abduction
  - Frequent reach above shoulders
  - Tasks which pull shoulders back and down
  - Prolonged load on shoulders
  - Repetitive throwing of heavy loads
- **Elbow**
  - Repetitive forearm pronation
  - Extreme rotation of the forearm
  - Extreme flexion of the elbow
- **Finger**
  - Vibrating tools
  - Repetitive ulnar deviation
  - Flexion of the wrist with effort
  - Forceful gripping
- **Wrist**
  - Repetitive forceful wrist extension/flexion
  - High speed finger movements
  - Palmar base pressure
  - Ulnar deviation
  - Rapid wrist rotational movement

The human body as a machine

Inputs
1. O_2
2. Food

→ Human Body →

Outputs
1. Heat
2. H_2O
3. External energy (work)
4. Internal energy (consumed by body)
5. Waste/by-products

- **Focus: How inputs are turned into work, through <u>metabolism</u>**

How much oxygen do we need?

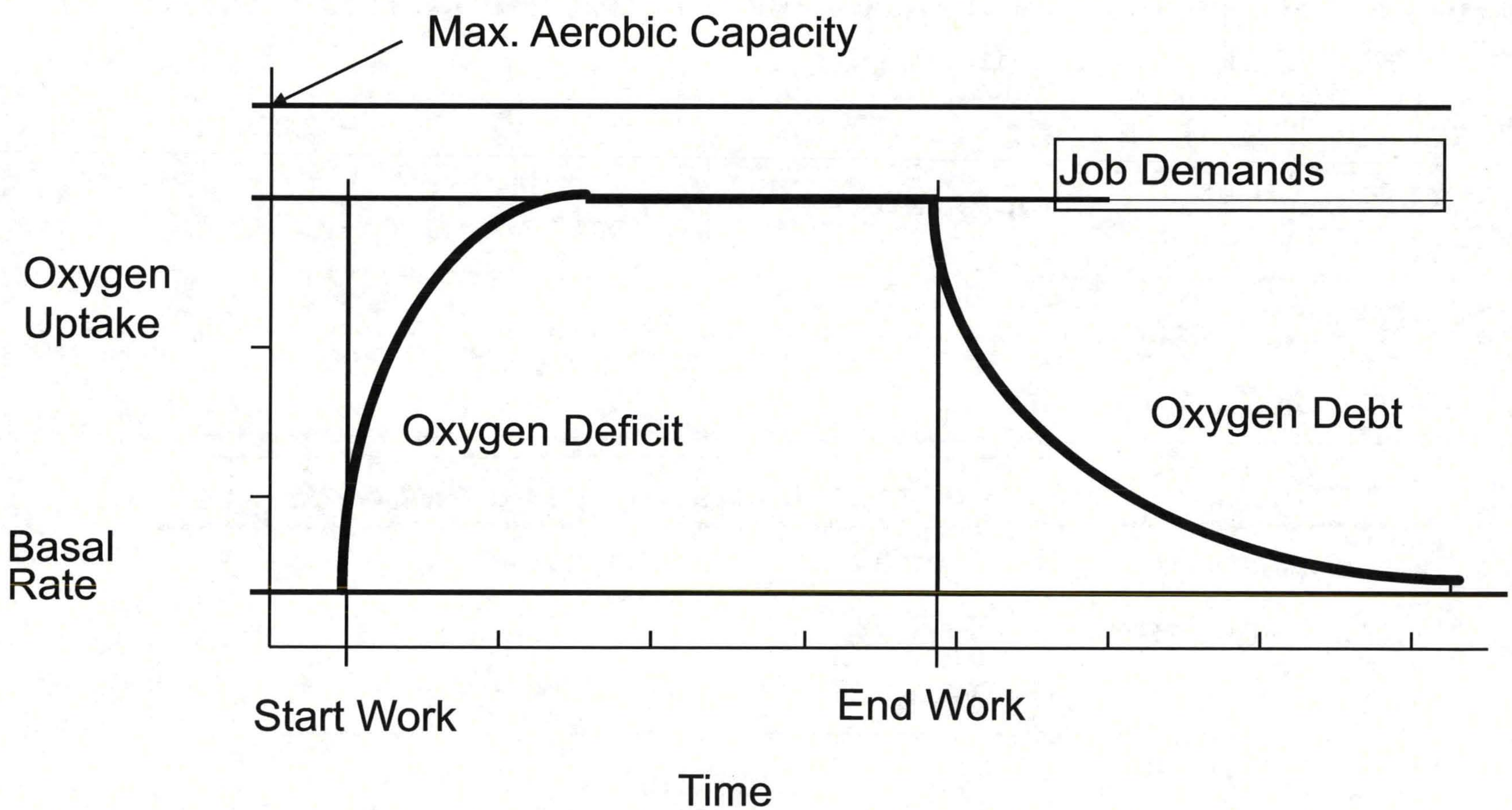
At sea level, atmosphere is approximately 21% O_2, 79% N_2

Guidelines for classifying work based on persons 20-30 yrs of age

- Other problems—ability to perform work depends on muscle mass, body size, cardiovascular endurance, etc.
- At rest, muscles use about 20% of oxygen in blood
- At medium work, muscles use about 70% of oxygen in blood

	O2 uptake	HR
Light work	up to 0.5 liter-min^{-1}	up to 90 bpm
Moderate work	0.5-1.0 liter-min^{-1}	90-110 bpm
Heavy work	1.0-1.5 liter-min^{-1}	110-130 bpm
Very heavy work	1.5-2.0 liter-min^{-1}	130-150 bpm
Extremely heavy work	>2.0 liter-min^{-1}	150-170 bpm

Oxygen Deficit: Sustainable



How much energy do we need from food?

- **Calorie: measure of energy in food**
- **Firefighters: over 6,000 calories per day**
- **The average adult needs 2,000 – 2,500 calories a day (dependent on body size, activity level, etc.)**
- **Macronutrients in food**
  - Carbohydrates: 4 calories/gram
  - Protein: 4 calories/gram
  - Fat: 9 calories/gram
  - (Alcohol: 7 calories/gram)

Macronutrient	**For astronauts**[1]	**The rest of us…**[2]
Protein	≤ 35%	10-35%
Carbohydrates	50-55%	45-65%
Fat	25-35%	20-35%

1. NASA HF Standards (link on Moodle)
2. http://www.mayoclinic.com/health/healthy-diet/NU00200

Thermal comfort

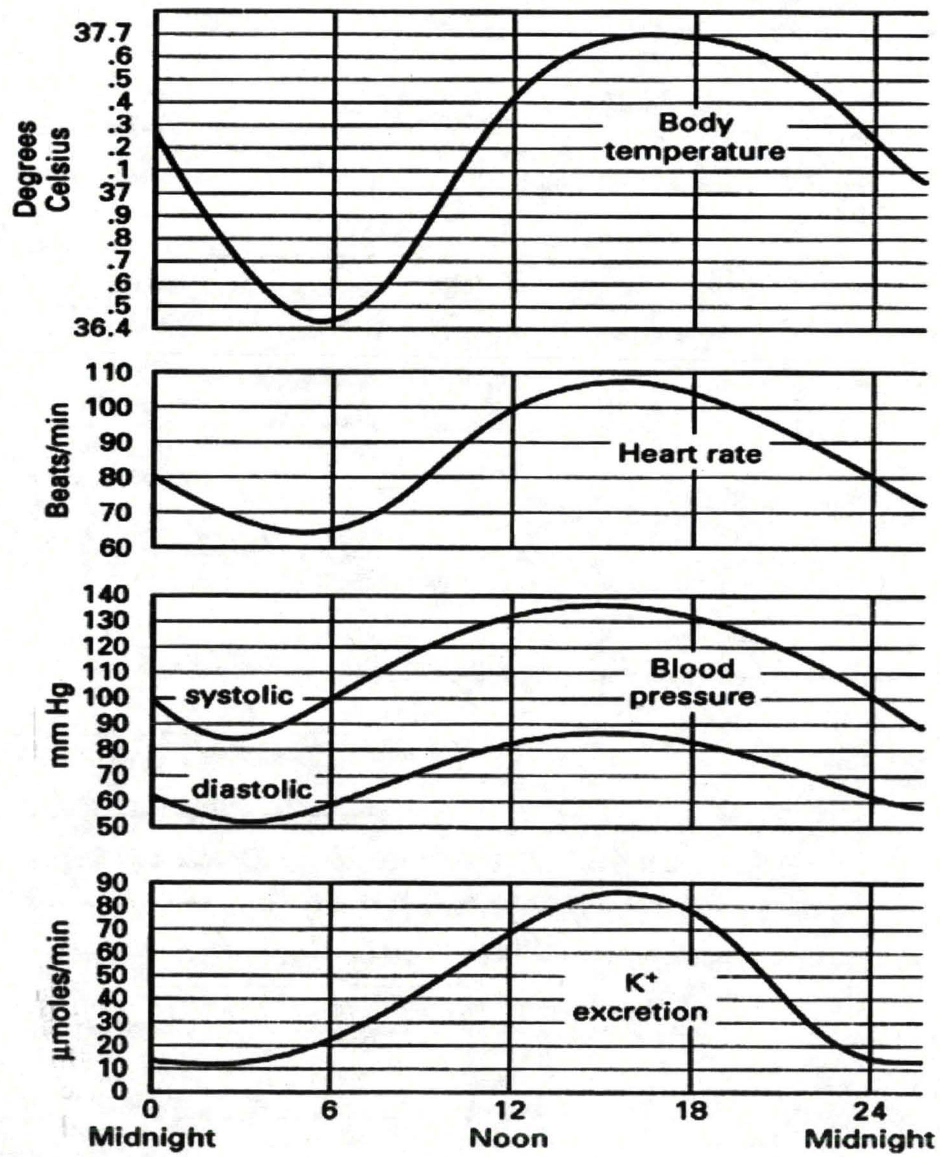
- **General human perceptions**
  - Too hot: weary, sleepy, decreased physical activity, more errors
  - Too cold: restless, decreased alertness, concentration, and motor skills
- **Comfort zone: 19-26° C (66-79° F), relative humidity 50%, and slow air movement**
- **On Shuttle, temperature range 64-81° F**
- **Goals (NASA):**
  - Avoid shivering from cold
  - Avoid actively sweating

Fatigue and driving

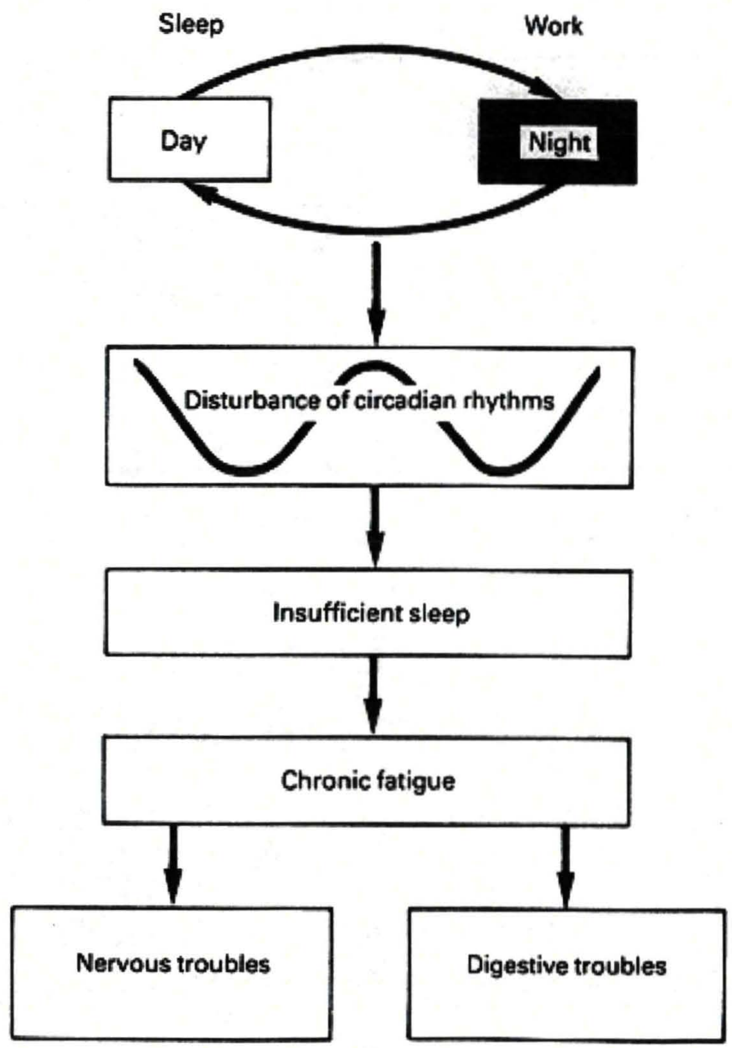
- **Fatigue associated with motor vehicle accidents**
  - 38% of commercial vehicle accidents due to being asleep or inattentive (Harris & Mackie 1972)
- **Behavior changes under fatigue**
  - Longer and delayed reactions to changing road demands
  - Fewer steering corrections
  - Reduced galvanic skin response to traffic events
  - More body movements (rubbing face, stretching, closing eyes)
- **Assisting fatigued drivers**
  - Personal: Take a nap, consume caffeine, get in bright light if nighttime, don't use cruise-control
  - Engineering: *Botts dots* between lanes or in medians and shoulders, Road surface changes near speed zones or stops
- **How does this research apply to extreme environments?**

3.4 Circadian Rhythms

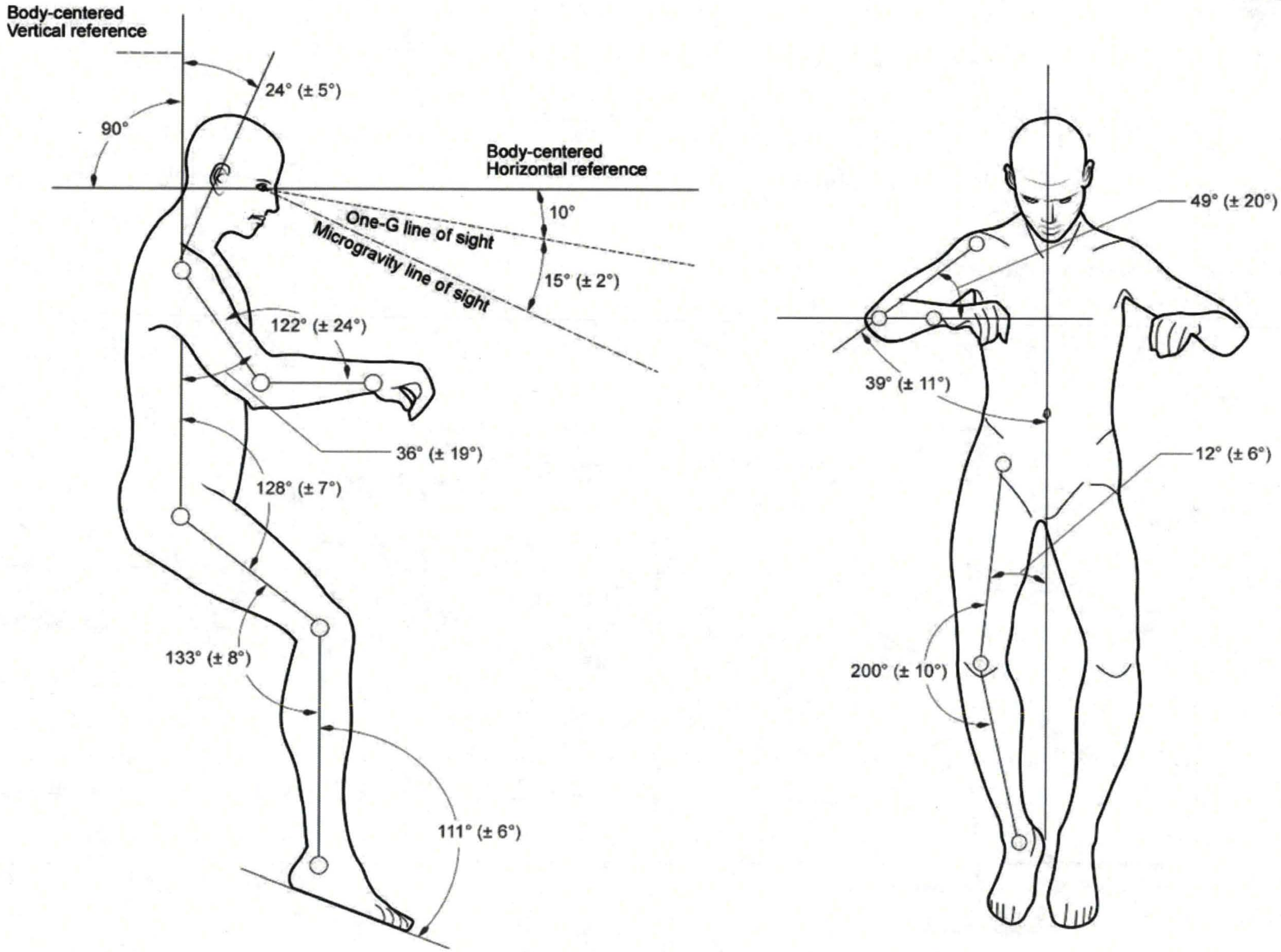
- **Biological rhythm: cyclic change in the physiological state of the body**
  - Circadian rhythms -- Period of 1 day (24 hours).
  - Affects body temperature, heart rate, blood pressure, potassium excretion
  - Also affects alertness



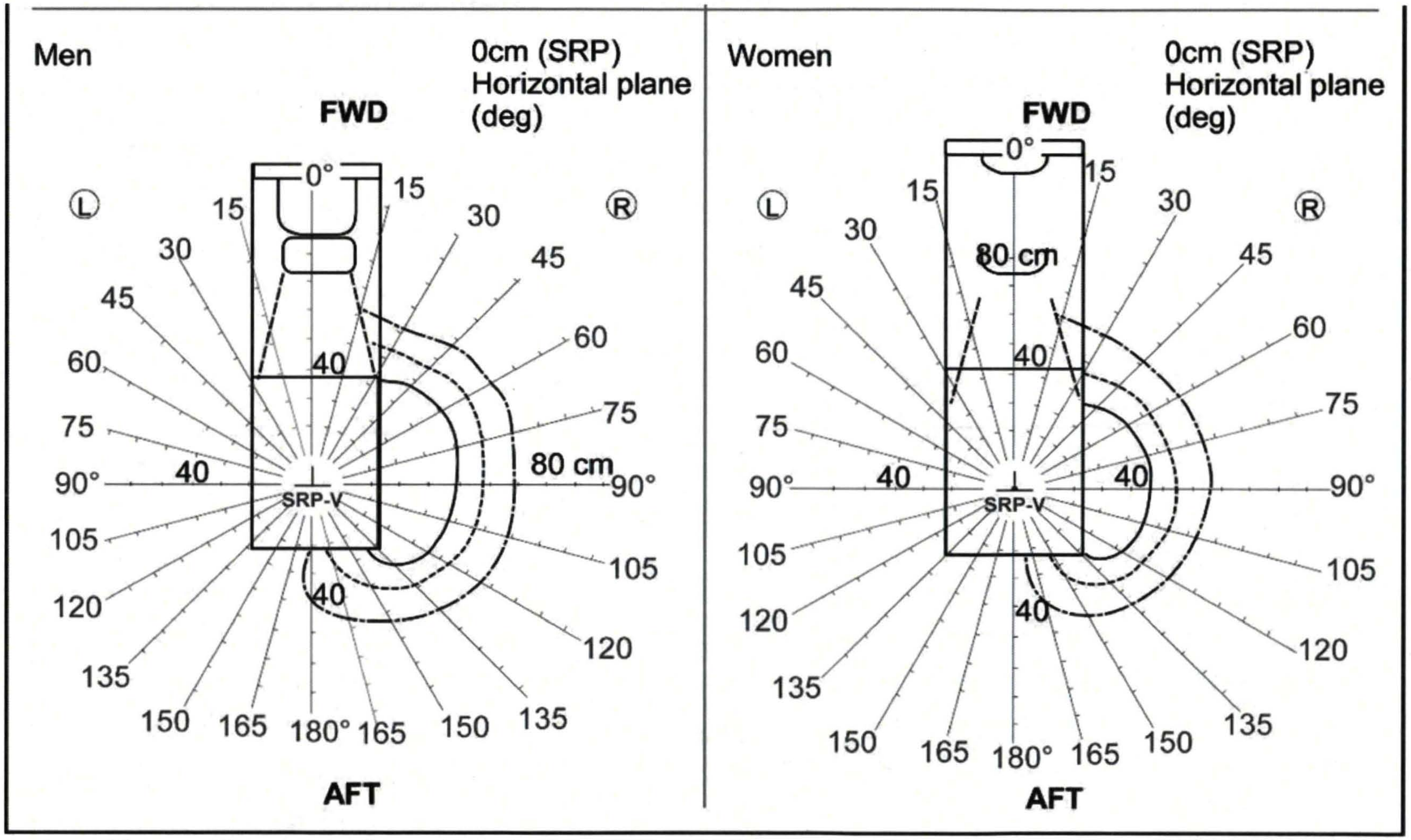
Nightwork and Health



Neutral body posture in 0g



Reach envelope example



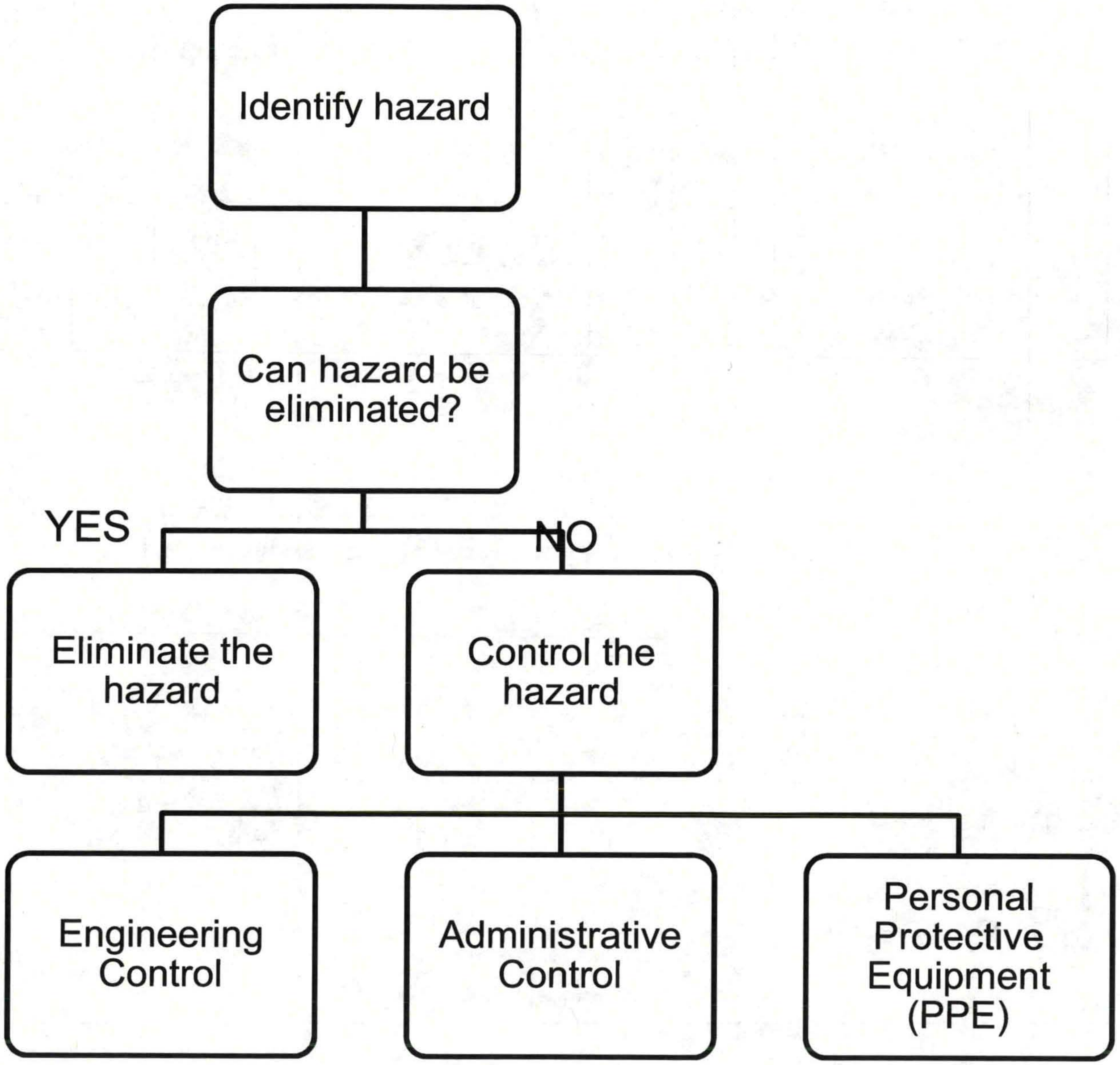
———— 5th percentile outer boundary and inner boundary (inner curve)

\-\-\-\-\-\-\-\-\- 50th percentile outer boundary

-·-·-·-·- 95th percentile outer boundary

NASA-STD-3000 288b

Hierarchy of Safety Controls

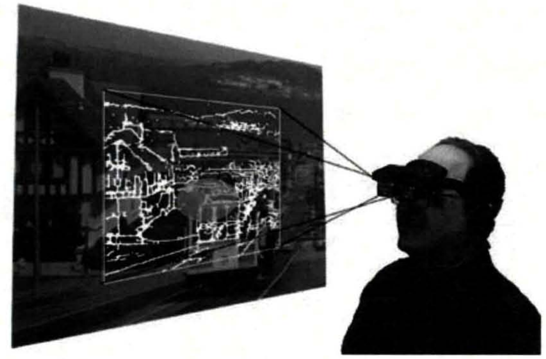


6.1.1 Displays

Standard

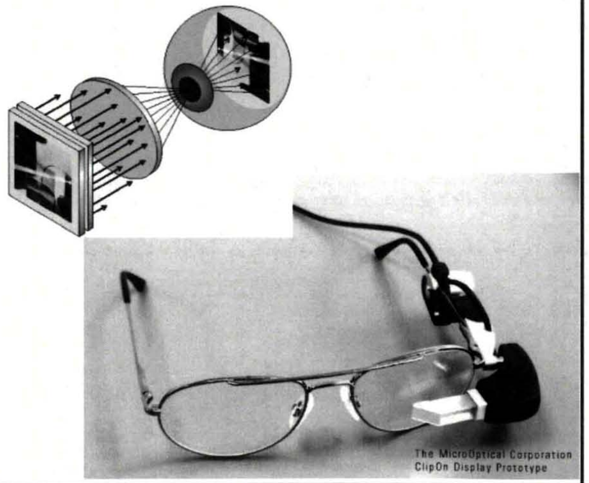
Hand-supported

Head-mounted



Heads-up

Virtual Retinal (VRD)



Spatial

6.1.4 Tactile and other input devices

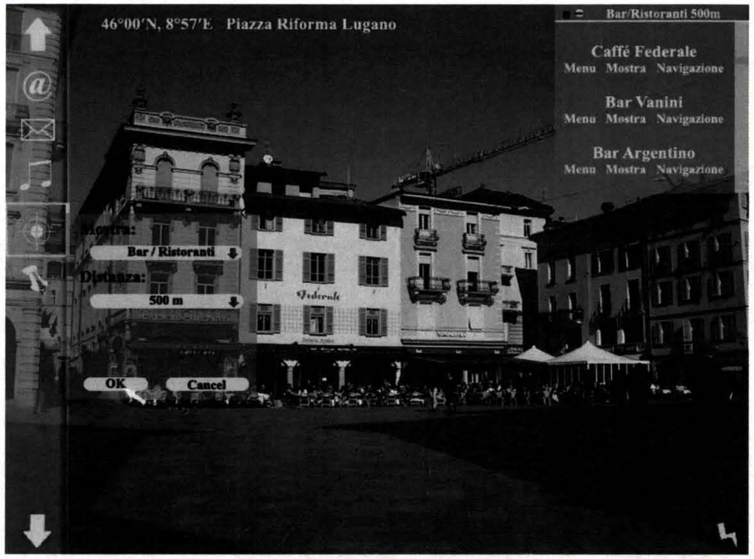
Other devices used to detect interaction gestures by the user with the AR system

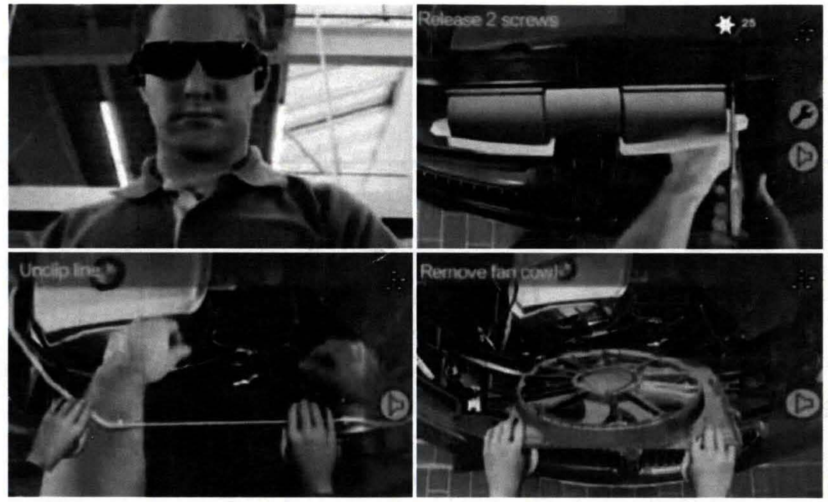
Ex) Pinch gloves:

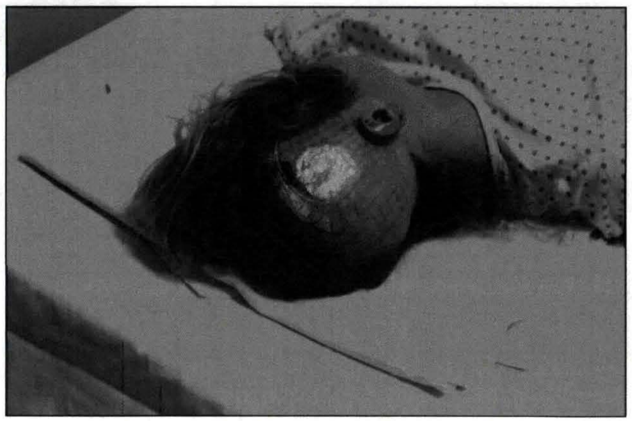
- Sensing gloves have embedded sensors which measure the position of each finger versus the palm.
  - Simple
  - Lack of need for calibration
  - Possibility to use both hands for gesture interaction
- Can only detect whether a contact is made or not and cannot measure intermediate finger configuration.

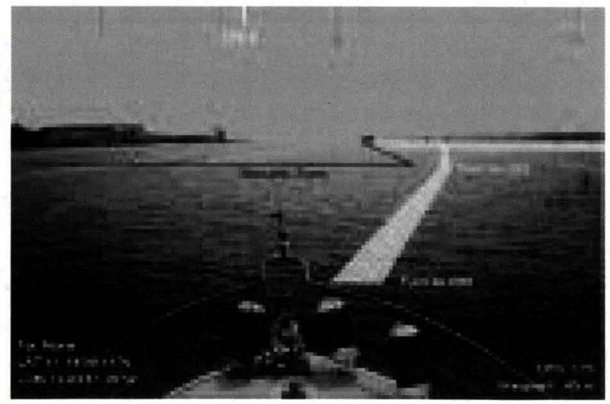
Ex) Voice recognition systems, wands, force pads, ...

6.1.7 AR examples









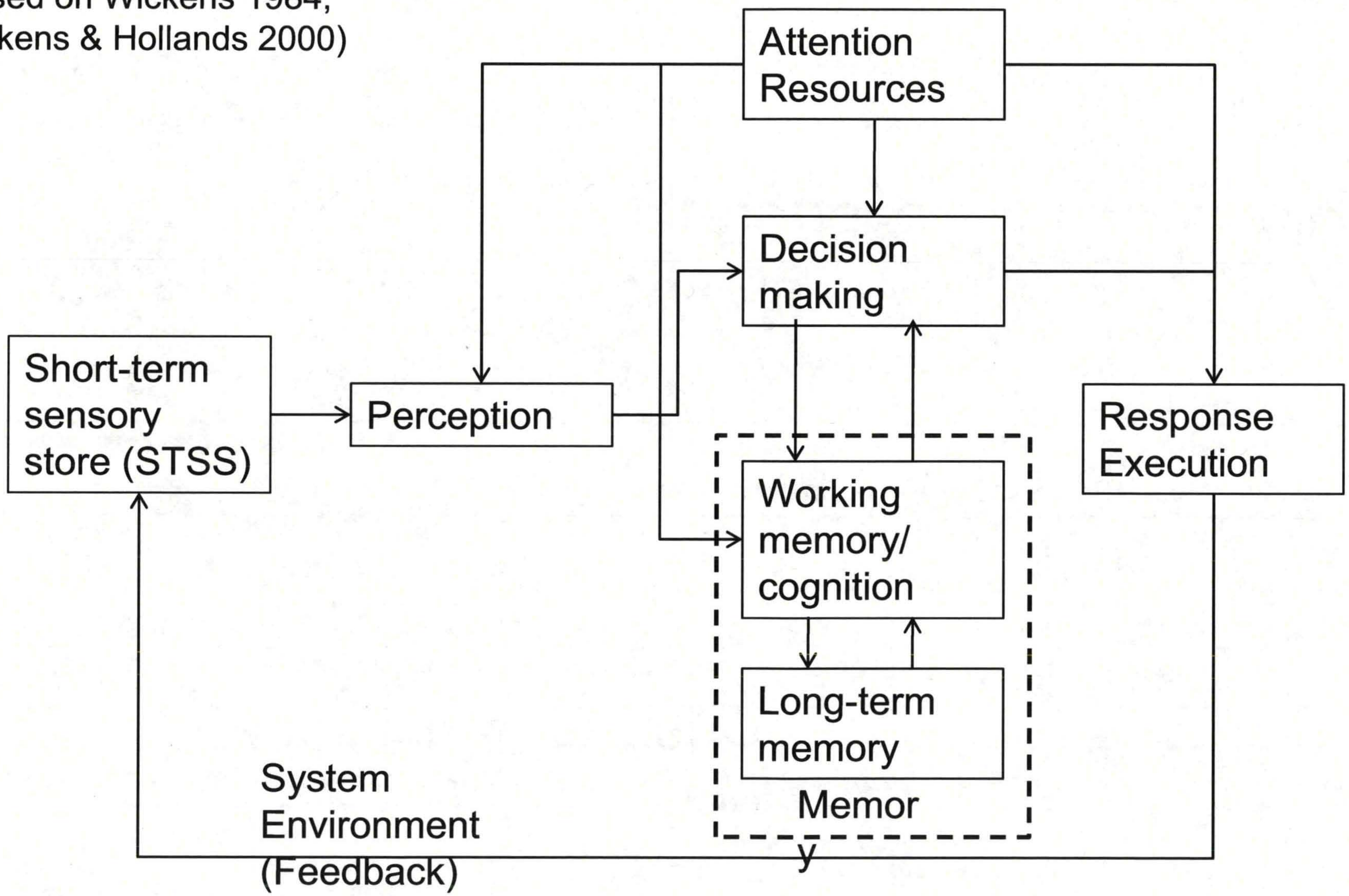
6.1.7 AR examples

6.2 Situational Awareness

- **Types of attention**
  - Ambient, divided, focused, selective, sustained
  - Single resource theory vs. multiple resource theory
  - Visual and auditory attention
- **Vigilance tasks**
- **Situational awareness (SA)**
  - Three levels (perception, comprehension, projection)
  - Effects of good/poor SA
- **Effects of environment, individual differences (e.g. age), training, fatigue, etc.**
- **Supporting tasks that require vigilance, high levels of attention, or high levels of SA**

Human Information Processing

(based on Wickens 1984,
Wickens & Hollands 2000)



What are some problems that arise when we divide attention among multiple activities?

Higher number of errors

Slower processing times

Decision-making sub-optimal

Improving performance in vigilance conditions

Increase sensitivity

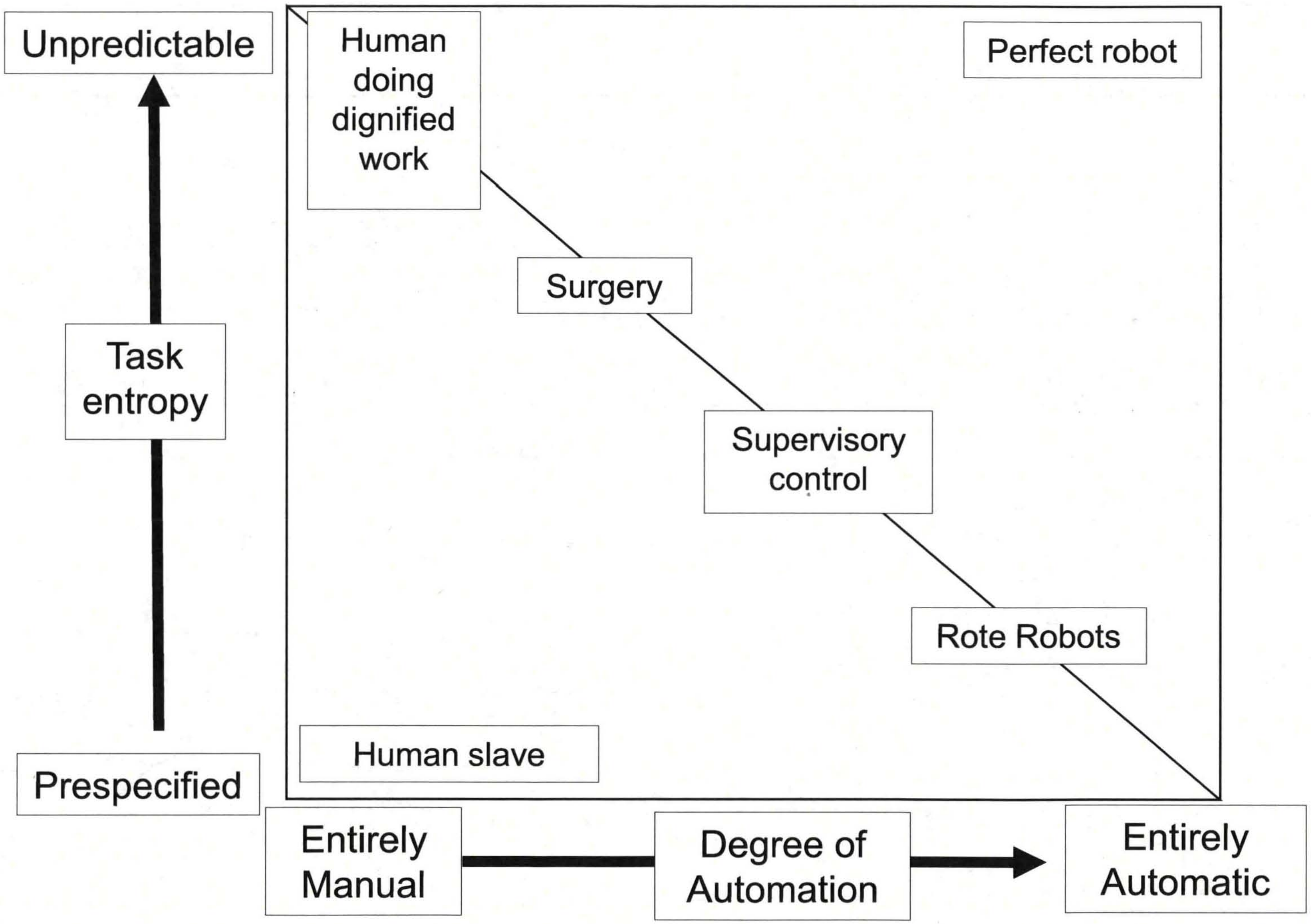
- Reduce workload
- Variable event/target rate
- Increase salience of signal
- Train to automaticity
- Provide appropriate work-rest schedules (reduce fatigue)
- Maintain an optimal ambient environment

Increase probability of detection

- Knowledge of results (KR)
- Instructions/rewards/payoffs
- Insert distracters
- Make clear the importance of the task

LSU

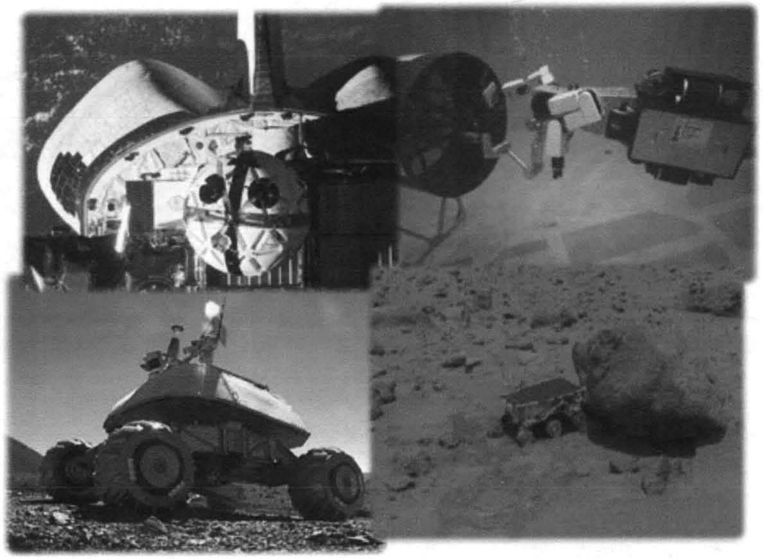
7.1 Levels of Automation/Control



Sheridan, T.B. (1992). *Telerobotics, Automation, and Human Supervisory Control*. Cambridge, MA: The MIT Press.

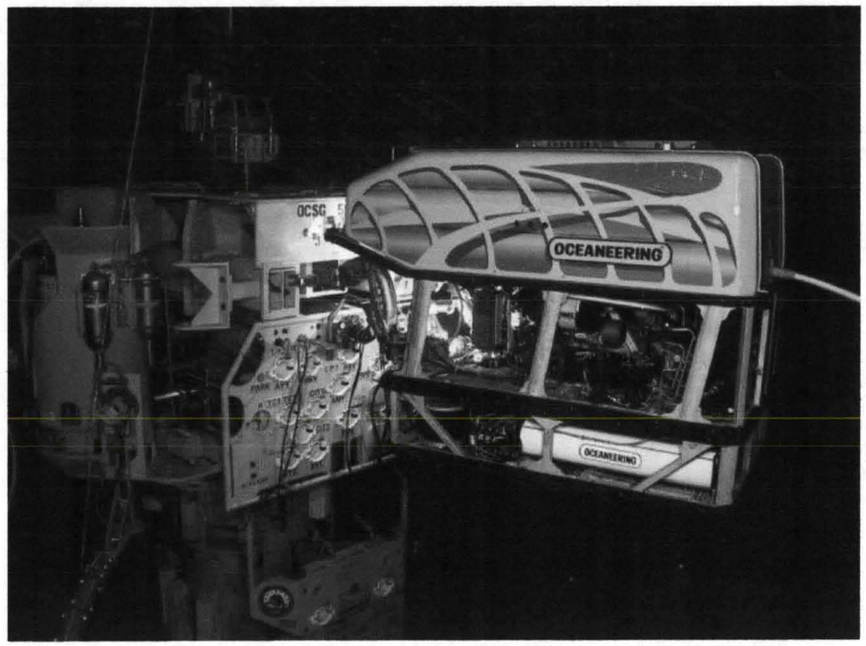
7.2.3 *Tele-robotics*

- **Telerobotics is the operation of robots from a distance through wireless or tethered connections.**



NASA telerobotic examples

Oil well telerobotics (e.g., BP robots)



Humans v. Robots

Humans	
Advantages	**Disadvantages**
•Are intelligent; adapt to unexpected situations	•Require sophisticated life support
•Are able to reason; produce creative solutions	•Have limited strength and steadiness
•Are flexible	•May work in varying ways
•Can do several things at the same time	•Are subject to stress
•Are dexterous when manipulating small parts	•Get tired, sick, bored, etc.
•Are ideal for unstructured environment	•Can't work as fast or slowly
	•Require visual cues to execute most tasks
	•Can't work in extreme temperatures

Robots	
Advantages	**Disadvantages**
•Are able to do repetitive tasks with high precision	•Can't adapt to recover to errors
•Are expendable (if cheap enough)	•Can't analyze a situation to find the next best step
•Can sense small motions, weak signals, etc., that humans can't	•Never deviate from an operational plan (can't abandon or change operational steps that no longer make sense)
•Can be stronger and larger or smaller than people	
•Never get tired, nervous, scared, etc.	
•Can be sterilized (avoids biological contamination)	
•Can work as fast or slowly	
•Can execute tasks without visual cues, can use machine vision that operates beyond human spectrum	

Larson, W. J. and Pranke, L. K. (1999). Human spaceflight: Mission analysis and design. The McGraw-Hill Companies, Inc., New York, NY.

8.1 *Networks & communication devices*

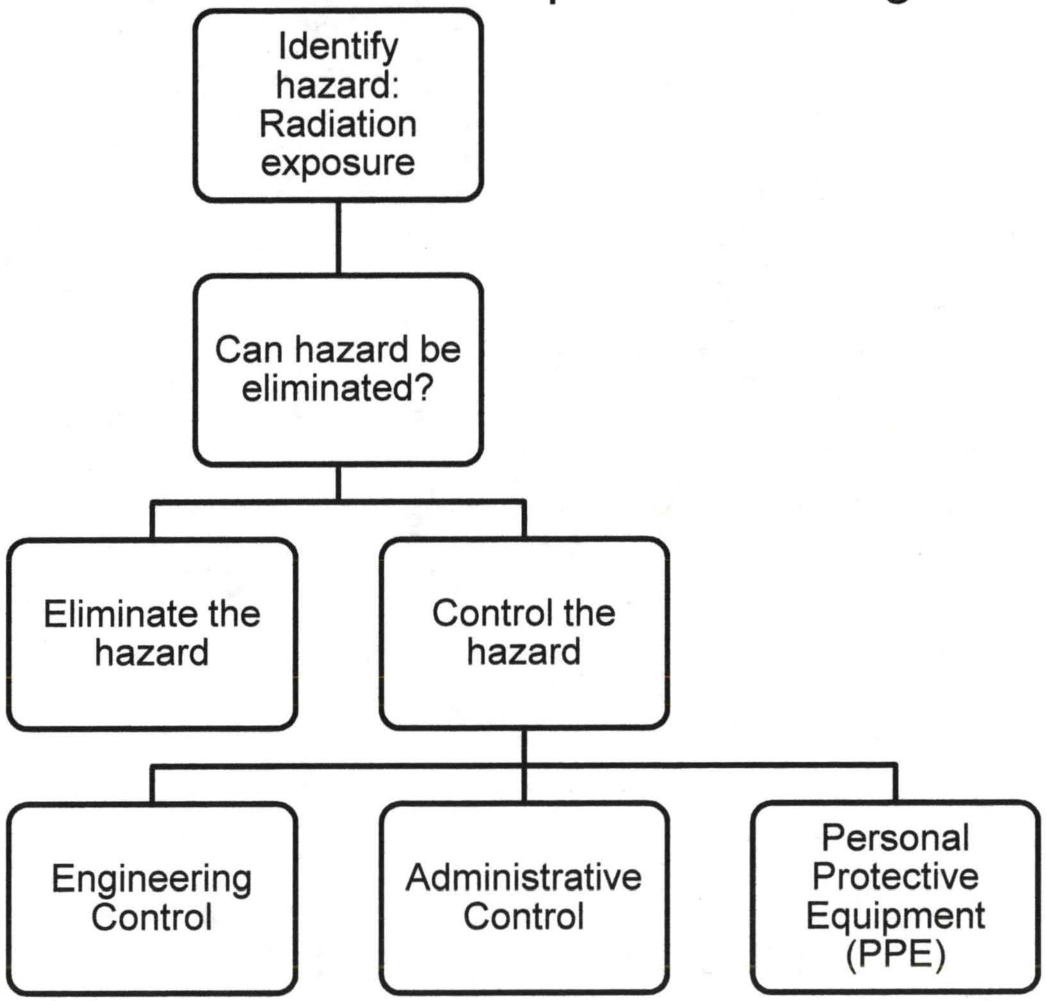
- **Issues:**
  - Data rate requirements:
    - Voice communications; simple sensor and status communications : low
    - Documents & compressed low/medium resolution pictures : medium
    - Video, high resolution imagery (including radar and multispectral imaging) : high
  - Power consumption
  - EMI / EMF
    - Electrical storms in atmosphere
    - Solar flares / wind in space
    - Atmospheric ionization
    - Equipment (compressors, generators, motors, welding or furnace devices, etc.)
  - Interplanetary
    - Time lags:
      - Radio signal Earth to mars: 3-22 minutes ONE WAY, depending on location of planets with respect to each other in their orbits.
    - Direct line of sight required
      - Geosynchronous satellites or other space objects around planet to relay from ground to space.
      - Relays may be needed between planets due to orbital considerations
        - For example, sun is between earth and mars approximately 2 weeks out of every approx. 2 years.

Extreme Environments Habitat Design: Exam Review

01. Space Operations Overview
NASA ESMD Capstone Design

Sample Question

- Radiation exposure is a major safety and health concern with space missions. Safety can be improved using the following hierarchy. Give an example of how humans can be protected using each level of the hierarchy.



Sample Question

- **Thinking about function allocation between machines and humans, give an example of one component in your project where your team will make the decision to use machines, humans, or a combination of both.**
  - 1. Name the component
  - 2. Discuss the limitations/constraints of this component that directly impact your choice of machine/human/combination
  - 3. Discuss why you would choose machines, humans, or a combination to interact with this component by referring to those constraints and incorporating the abilities and limitations of humans and current technology.
- **(Note: this question would be too long for the test, but gives you an idea of the type of thinking you need to do)**

Assessment

- Laura Input

Lessons Learned

- Gerry/Laura/Craig input

Habitats in Extreme Environments Faculty Activity

- NASA Project Topics : team brainstorming, report out, group discussion